# TACTILE ACUITY AND RELATED PERCEPTUAL PROCESSES IN BRAILLE CHARACTER IDENTIFICATION

COLIN. H. PEAK
8 BOLWARRA AVE
WEST PYMBLE
. SYDNEY
AUSTRALIA 2073

# AN INVESTIGATION OF TACTILE ACUITY AND RELATED PERCEPTUAL PROCESSES IN THE IDENTIFICATION OF BRAILLE CHARACTERS

C. H. P E A K

A thesis submitted for the degree of
Master of Arts (Honours)

Department of Psychology University of Sydney

December 1989

## Acknowledgements

In submitting this thesis I should like to acknowledge the generous help I have had from staff members of the Psychology Department at all stages of my research project.

My particular thanks are extended to Professor Phil. Sutcliffe for his patient supervision of the research and for advice and suggestions which served to clarify many difficult points of procedure and interpretation during the course of the project.

I am indebted also to other members of the Psychology Department , to George Oliphant for reading through the draft report and for advice on presentation of some of the research material, to Dave Grayson for assistance in overcoming a tricky statistical problem. I also extend my thanks to George Henderson for arranging construction of apparatus for the research and to members of the technical staff for the excellent job they did in providing me with a piece of equipment which worked faultlessly throughout the experiment.

The preparation of braille tapes for the project was kindly undertaken by staff of the Royal Blind Society of NSW and I am indebted particularly to Mrs Joan Lederman who arranged to have the tapes prepared and Maria Poulos who typed up the embossed characters on the tapes.

Finally I must pay tribute to my wife Joan for her continuing interest in the research and for her forbearance over a lengthy period during which the braille project often took precedence over normal plans and activities and I am sure quite often sorely tried her patience.

# Acknowledgements

In submitting this thesis I should like to acknowledge the generous help I have had from staff members of the Psychology Department at all stages of my research project.

My particular thanks are extended to Professor Phil Sutcliffe for his patient supervision of the research and for advice and suggestions which served to clarify many difficult points of procedure and interpretation during the course of the project.

I am indebted also to other members of the Psychology Department, to George Oliphant for reading through the draft report and for advice on presentation of some of the research material, to Dave Grayson for assistance in overcoming a tricky statistical problem. I also extend my thanks to George Henderson for arranging construction of apparatus for the research and to members of the technical staff for the excellent job they did in providing me with a piece of equipment which worked faultlessly throughout the experiment.

The preparation of braille tapes for the project was kindly undertaken by staff of the Royal Blind Society of NSW and I am indebted particularly to Mrs Joan Lederman who arranged to have the tapes prepared and Maris Pennos who typed up the embossed characters on the tapes.

Finally I must pay tribute to my wife Joan for her continuing interest in the research and for her forbearance over a lengthy period during which the braille project often took precedence over normal plans and activities and I am sure quite often sorely tried her patience.

# SUMMARY


A paper by Sutcliffe (1986) raised the possibility of a more efficient employment of codes of the braille alphabet based on allocation of most highly differentiated codes to letters of greatest frequency of use in ordinary print material. Such a reallocation of codes would only achieve the object of easier and quicker letter identification if areas of the finger pad skin making contact with the three rows of the braille matrix were not differentially sensitive to pressure of dot protuberances. If receptors were differentially sensitive in these three regions an advantage based on code to code objective differentiation would be effectively diluted.

Research to test for differential regional sensitivities consisted of presentation of codes with either one dot or two dots located in single rows of the braille matrix with other row positions empty. Subjects were required to make an identification of dot number and dot position. Errors of identification of dot number showed no significant differences between rows and it was concluded as a result that under conditions simulating the normal braille reading situation no systematic sensitivity advantage existed for any of the three regions of the finger pad corresponding to rows of the braille matrix.

Dot positioning results though not appropriate to the test of regional sensitivity because of confounding factors involving judgements of spatial reference points , contributed to an understanding of the processes by which dot patterns are identified. Positioning errors were found to be variable depending on row and column location of dots and since a similar variability was not apparent in the case of dot number it was hypothesized that the two operations of identification of dot number and dot position were served by different neural pathways. Both operations were however found to be subject to severe constraints in relation to increases in information load and it was concluded that processing of punctate data is quite slow and that errors of identification result from decay of short term memory registers before these are fully scanned.

Implied in this conclusion is an analytic model of dot pattern identification the main feature of which is scanning of trains of short term memory registers established as dot protuberances pass across the finger pad surface. Since dots in the two columns of the braille matrix traverse the finger pad simultaneously two trains of impulses are

transmitted to the brain. This is assumed to set up a dual series of short term memory registers and the alternation of attention between column registers and between registers and the temporal event signifying movement between columns , provides a plausible explanation of errors involving misreading of vertical arrangements of dots as rows or diagonals and diagonal arrangements as verticals.

Implications of the research for the reallocation of braille codes are favourable in that there appear to be no substantial sensitivity differences across that area of the finger pad surface in contact with the three rows of the matrix. Analysis of dot positioning errors however indicates an inherent problem in the three row structure of braille codes and this appears to be a major barrier to improvement in reading speeds using the present braille code system.

CONTENTS

**Appendix 3.** Objective differentiation of braille matrix cell positions for codes representing the 26 letters of the alphabet

**Appendix 4.** Comparison of recognition time and objective difference rank orders of braille alphabet codes.

**Appendix 5.** Experimental apparatus.

**Appendix 6.** Order of presentation of braille stimuli.

**Appendix 7.** List of instructions for administration of tests.

**Appendix 8.** Three dot braille codes : dot number and dot position analysis.

**Appendix 9.** Subject Protocols : 1, 2 and 3 dot codes.

**Statistical Appendix 1**

**Statistical Appendix 2**

## 1. INTRODUCTION

The research reported in this document has to do with tactile sensitivity and its interaction with central processes in the identification of punctate characters of the 3 x 2 braille matrix. The original suggestion for the research came from a paper by J.P.Sutcliffe (1986) which described a generalized method for establishing an order of difference between components of an objects x attributes matrix. The method can differentiate objects in terms of attribute differences or differentiate attributes based on object differences and can also provide conditional orderings within object or attribute classes.

The paper by Sutcliffe used the braille code as a convenient exemplar of an object x attribute matrix demonstrating the ordering procedure. Objects in this exemplar can be defined in a number of ways - as a sampling of braille texts , as words within braille text or as letters of an alphabet. For convenience of exposition the braille codes corresponding to the 26 letters of the English alphabet were designated as objects. Any set of characteristics which could be used to describe the codes could then be selected as attributes. In the example the six positions of the braille cell (see illustration below) were selected for this purpose. For each letter code then , each of six attributes could take one of two values , either presence or absence of a raised dot or protuberance :

| | |
|---|---|
| 1 | 2 |
| 3 | 4 |
| 5 | 6 |

**(Numbers are shown in cell positions for convenience of reference later in the report)**

By comparing each braille letter code with codes for the remaining 25 letters and noting cases of coincidence, either of presence or absence of a dot protuberance in each of the six dot positions, the 26 codes can be ordered in terms of the number of correspondences, or conversely , by counting differences from all other objects over the six attributes , an ordering can be made in terms of the number of such differences.

Judged on these measures the letters of the braille alphabet were found to display substantial variability in the number of

differentiating dot/no dot correspondences and could be ordered accordingly. For example, summed over the six positions of the braille cell, the letters 'p' and 'q' each had a total of 58 differences (consisting either of presence or absence of a protuberance) relative to the other 25 letters of the alphabet. By contrast the letter 'w', the best differentiated letter, has a total of 92 differences. On this criterion the commonest appearing letters in English, 'e' and 't', are not well differentiated. The letter 'e', for example, has a count of only 68 differences. A full tabulation of differences for the 26 alphabetic codes is shown in Appendix 1 ( see Appendix 2 for the actual braille codes ).

If, instead of ordering objects, defined as braille codes for letters of the alphabet, the 6 positions in the braille cell are ordered by count of the number of times letters are differentiated from each other within a matrix position in terms of presence or absence of a protuberance, position attributes are also found to possess variable differentiating properties. The mid-range positions (positions 3 and 5 in the above illustration) have the largest number of differences, the top and bottom peripheral positions the least number.

It is clear from these analyses that the braille alphabet, judged solely on its physical structure, falls short of an optimum exploitation of the differentiating properties of the 3 x 2 matrix. As pointed out above, the most commonly used letters of the English alphabet are not those which are best differentiated and, more importantly, the positions which, because of the way the braille code is constructed, are best able to differentiate, are not allocated in a manner which takes advantage of this differentiation. The letters "p", "q", "m" and "n", for example, all use the mid-range positions efficiently, that is all four have most differences in positions 3 and 4 ( see Appendix 3 ), but this advantage is offset by poor differentiation in other positions. The best differentiated letter, "w", occupies this priority rank by virtue of an absence of a protuberance in position 1 and presence of one protuberance in position 6, both of which conditions place it among a small minority of letters; in the remaining four cell positions the letters are more evenly split between the two conditions and the presence or absence of a dot does not affect the differentation "w" obtains from the positions 1 and 6.

Given that the braille alphabet is not constructed such that the best differentiated codes are allocated to letters which appear most frequently in printed matter, it is natural to ask whether it is possible to devise a system of braille codes which makes full use of the properties of

the braille matrix. A reallocation assigning the present codes for "w", "j", "z" and "u", all of which are among the best differentiated letters, to letters which are more frequently used, would, for example, appear to provide an opportunity for easier recognition of codes.

It could be objected that this would be merely tinkering with the system, that an ideal arrangement would be one in which there was a one-to-one correspondence between the magnitude of differences between letters of the alphabet judged on frequency of use on the one hand and on objective criteria on the other. To give this allocation its maximum differentiating capability a further condition would be that the objectively measured distance between the least and most differentiated code should itself be a maximum.

It is clear that a code allocation best able to approximate to these conditions would be achieved by selection from the full set of cell configurations. The use of the full set instead of a sample of codes would allow maximization of differences but such an unrestricted selection would mean a substantial recasting of the braille system since all of the 63 available codes are employed for ordinary text: codes not used for letters are used either for punctuation marks or contractions.

The situation is further complicated by the use of single codes to convey different meanings in different contexts. The code for the letter "s", dots 2-3-5, for example, has no fewer than six other meanings depending on which codes precede or follow it: standing alone it is used for the word "so", preceded by the single dot 4 it means "some", preceded by dots 2-4-6 it stands for "spirit", by dots 2-6 it stands for the contraction "-less", by dots 4-6 the contraction "-ness", and followed by dot 4 it stands for a section sign.

A rearrangement of codes based on the requirement of maximum objective differentiation would accordingly need to take into account not only the frequency of use of letters, punctuation marks and simple contractions but also the multiplicity of contextual contractions and usages. It would obviously mean a complete redevelopment of the system from the ground up.

The prospects for acceptance of a modification of this order are minimal, bearing in mind the international use of the braille system and the strong sense of custodianship among individuals and organizations whose recent efforts have led to standardization of the codes. These obstacles to change have not, however, stopped research efforts aimed at a

better understanding of perceptual factors involved in learning and reading braille and the present research, while it takes as its starting point the premise that the 3 x 2 matrix is not used to best advantage, is essentially an extension of this exploratory research.

At this point, before proceeding to a discussion of the aims and structure of the present research, it will be appropriate to give a brief outline of the history and development of the braille system and some details of the present status of research on sensory/perceptual aspects of braille use.

## 2. THE BRAILLE SYSTEM OF READING

The basic element of the braille system is the 3-row/2-column matrix as shown diagrammatically in the introductory section of this document. Raised dots in different configurations within the matrix are used to denote letters of the alphabet, punctuation marks and whole or part word contractions. Specifications of dot and matrix dimensions used in the printing of braille do not appear to be subject to strict standardization but as far as can be judged, consist of a range of acceptable values within which individual institutions operate. Locally, the Royal Blind Institute of N.S.W. keeps no record of cell and dot dimensions since all braille printing machinery is imported and specifications are therefore for all practical purposes beyond their control.

Two American references give conflicting values of matrix dimensions. Nolan and Kederis (1969), quoting Zickel and Hooper give the following as standard measurements in the USA at the time of publication of their book : base diameter of raised dot 0.060 inches ; height of dot 0.017 inches ; distance between centres of vertically or horizontally adjacent dots within the cell 0.090 inches ; distance between centres of dots in corresponding positions in adjacent cells in the same line 0.160 inches ; distance between centres of dots in corresponding positions in adjacent cells in adjacent lines 0.220 inches.

Foulke in a later publication (1982) provides only a height range of 0.02 and 0.05 cm (0.015 and 0.020 in.) for the dots themselves but gives single value interdot and intercell measurements which vary in some instances from those given by Nolan and Kederis. Following the same order as above, starting with same cell interdot difference, values are : 0.23 cm.(.090 in.) ; 0.64 cm. (0.250 in.) and 1.02 cm. (0.40 in.).

( Dot dimensions in material prepared by the Royal Blind Institute for the present research are within the range of the above measurements. Height of dot is 0.5 mm and interdot distance 2.5 mm both for horizontally and vertically adjacent dots ).

The 3 x 2 matrix in its present form has remained unchanged in the 150 odd years since the first publication of the system by Louis Braille in 1829 and the dot codes used by Braille for the letters of the alphabet are also identical except for the addition of a code for the letter "w" which was not used in the inventor's native French. Apart from this addition , the major development since the early days of Braille has been the adoption of single letter codes for contractions consisting of two or more letters or whole words. In this development all 63 possible combinations of the six positional dots have been used and many codes have been assigned multiple uses, an example of which has been given in the introduction above. To achieve a consistent use of these coding arrangements, agencies for the blind in the U.S.A. and the United Kingdom agreed at a meeting in 1932 on a standardization of the system for the English speaking world and meetings from time to time since that date have agreed on further modifications. The braille system has accordingly achieved a degree of institutionalization which seems likely to ensure its continued use in something like its present form for the foreseeable future.

The general acceptance of braille has however not been rapid or without misgivings and there continues to the present day a dissatisfaction with it as a system of communication for the visually impaired members of the population . This has led to the investigation of alternative codes such as "Vibratese" and the development of devices to enable the blind person to read ordinary printed script without the need for a code, the Optacon machine being the best known of these.

The main cause of dissatisfaction with braille has been and still is the slow reading speed achieved by even skilled users. Foulke (1982) cites fairly recent studies in the United States indicating an average speed of 60-80 words a minute by blind high school students compared with an average of 250-300 words per minute for their sighted counterparts. Nolan and Kederis quote speeds of 149 wpm claimed by Lowenfeld and Abel and 200 to 300 wpm in a study by Grunwald but dismiss these claims as spuriously high and due to atypical measures of reading , e.g. absence of comprehension test , use of materials below the capabilities of subjects. Earlier studies conducted by Hayes in 1919/1920 , reported by Nolan and

Kederis , indicate reading rates similar to those reported by Foulke. The Hayes studies are of interest as they were carried out before the introduction of most contracted forms and what appears to be a minor improvement in reading rates following their introduction throws some doubt on the effectiveness of these forms. Hayes, in reporting his rates asked: "Are we justified in requiring blind pupils to undertake the difficult and tedious process of learning to read with the fingers if we cannot bring their average reading rate above 60 wpm ? How many graduates will continue reading if they must read so slowly ?" Nolan and Kederis , 50 years later , add their own comment to this complaint: "Educators still ask this question."

On this same point of braille difficulty Geldard's comment referring to adaptability of the organism in use of various cutaneous communication devices should be noted : "........on this scale ( i.e. adaptability) history has already recorded the extreme difficulty of the Braille language...." (1974 ). To give a more precise dimension to the problem it is also worth mentioning an Encyclopaedia Britannica article (1962) citing a survey conducted in the United States in the 1920's which found that only 15% of the blind population read braille well enough to make reading a pleasure.

Conversations the present writer has had with staff of the N.S.W. Royal Blind Institute indicate that difficulty in learning and use of the script is found principally among people who lose their sight later in life and for whom learning braille involves a substitution for the Roman letter system of normal sighted reading. The figure quoted in the Encyclopaedia Britannica may therefore not be representative of the group of braille users who have never known any other form of reading. At the same time the adventitiously blind ( individuals who were originally normally sighted) apparently constitute a majority of the visually handicapped population and their difficulty with the script is therefore a significant part of the overall problem .

In spite of the apparent shortcomings of the braille system , there is little evidence of a readiness to subject it to a drastic overhaul. Foulke warns against expecting any such change : " The present standardization is only a recent achievement , and those who defend it are understandably alarmed by proposals that threaten it. Accordingly , if expansion of the present braille code is to be considered, its advantages must be demonstrated beyond question. " ( p 205).

The degree of unanimity on the poor performance of the braille

system is not however matched by a similar level of agreement on factors impeding attainment of satisfactory reading speeds. It is agreed that poor resolution power of cutaneous receptors is a major obstacle to any form of communication using the skin but there is also a body of opinion that difficulties specific to the braille system of codes limit reading speeds. Before looking at the braille specific factors, however, a brief account will be given of the present state of neurophysiological research dealing firstly with the structure and function of mechano-receptors of the finger pad skin and secondly with cortical structures involved in processing of tactile sensory input.

## 3. PHYSIOLOGICAL BASES OF TACTILE DISCRIMINATION

### 3.1 Pressure Receptors of the Finger Pad

Receptors in the skin of the finger pad consist of two main groups, free nerve endings and encapsulated nerve endings. The latter group, consisting of Meissner corpuscles, Merkel tactile discs and Pacinian corpuscles plus the Ruffini endings are now considered to be the receptor structures responsive to tactile stimulation of the skin. Merkel discs are located in the intra-epidermal tissue, Meissner corpuscles in the papillae (ridges at the junction of the epidermis and dermis), Ruffini endings in the dermal tissue and Pacinian corpuscles, the largest of the specialized receptors, in the sub-cutaneous tissue. A diagrammatic representation of skin tissues indicating the location of receptors is shown below (the diagram is a composite and does not represent a specific tissue type).

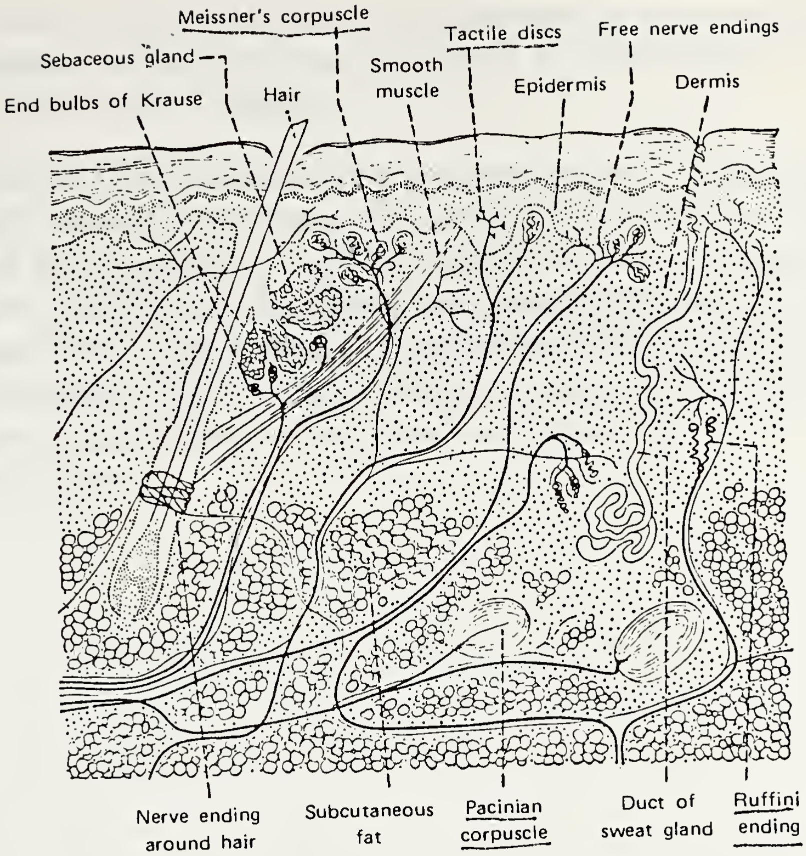



Fig. 9–6. Composite diagram of the skin in cross section. The chief layers, epidermis, dermis, and subcutaneous tissue, are shown, as are also a hair follicle, the smooth muscle which erects the hair, and several kinds of nerve endings. In the epidermis are to be found tactile discs and free nerve endings; in the dermis are Meissner corpuscles, Krause end bulbs, Ruffini endings, and (around the base of the hair) free terminations. The subcutaneous tissue is chiefly fatty and vascular but contains Pacinian corpuscles, the largest of the specialized endings. From Gardner (*216*) after Woollard, Weddell, and Harpman (*652*). By permission of W. B. Saunders Company, Philadelphia.

The work of Vallbo and Johannson (1978) has led to a better understanding of the specific functions of each of these receptor types. Using a procedure involving insertion of needle electrodes made of fine tungsten percutaneously into individual neural units in the median nerve of the upper arm, the authors were able to administer a range of tactile stimuli and note the functional characteristics of a large number of units.

Four main types of mechanoreceptor fibres were described which Vallbo and Johansson tentatively associated with the Pacinian, Meissner, Merkel and Ruffini receptor endings. Two fibre types were rapid adapting, that is they responded to the onset and end of pressure on the skin but not to constant deformation of tissue. One of these fibres had small, well defined receptive fields (RA) and was tentatively identified

with the Meissner corpuscle, the other (PC) possessed a large receptive field with indistinct borders and was considered to have axonal attachment to the Pacinian corpuscle.

The two other neural units were characterized as slow adapting and accordingly responsive to static pressure on the skin surface. Again one of the slow adapting fibres (SA1) had small, well defined receptive fields, the other (SA11) large, ill-defined receptive fields. These two units were considered likely to correspond to the Merkel disc receptors (SA1) and the Ruffini endings (SA11). The following table from the Vallbo and Johansson paper summarizes the characteristics of the four mechanoreceptor types:

TABLE 1 Types of Tactile Sensory Units in the Glabrous Skin of the Human Hand

| | | Receptive field characteristics | |
|---|---|---|---|
| | | distinct borders<br>small size<br>several sensitivity maxima | indistinct borders<br>large size<br>a single sensitivity maximum |
| Adaptation | rapid - no static response | RA | PC |
| | slow - static response present | SA I | SA II |

Of the four fibre types, Vallbo and Johansson found the RA and SA 1 had the highest concentration at the finger tips (see illustration below) and concluded that these were responsible for spatial discrimination in this skin area.

A. B. Vallbo and R. S. Johansson

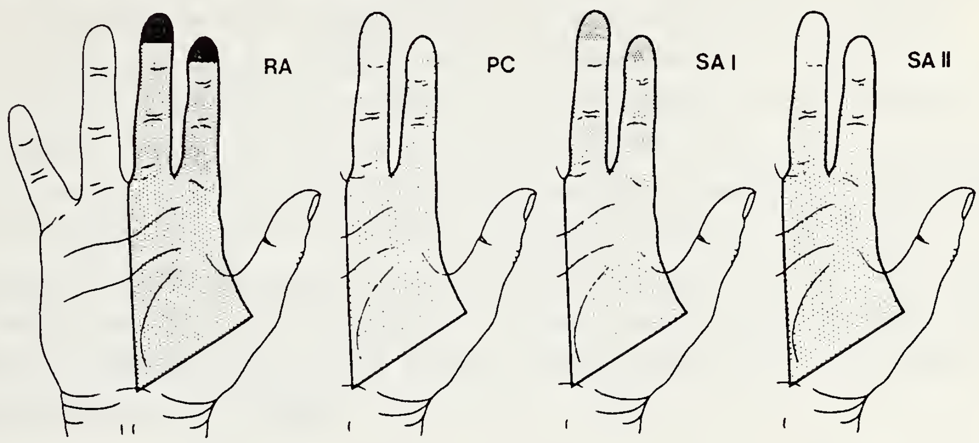



Fig. 10. Estimated absolute densities of the four types of tactile sensory units in the glabrous skin. Each dot represents a single sensory unit innervating the skin area. It should be emphasized that the figure illustrates only the average unit density within the region whereas the dot size and the exact location of the individual dot in relation to the neighbours has no relevance with regard to receptive field size and spatial distribution of fields.

The problem in an assumption of this kind is that it depends on an inference that because there is a similar proximo-distal gradient both in the two point limen (smallest distance at which two stimulus points are judged as two not one stimulus) and in the density of innervation, the two are functionally related. Such a relationship is not of course proof of causal connection and the discriminatory process does in fact appear to be more complex than can be explained by patterned firing of either the RA or SA1 receptor populations.

The danger of accepting a too simplistic account of fibre function is illustrated by results of an investigation by Johnson and Lamb

at Melbourne University (1981) in which braille-like dots were used as stimuli to establish the spatial resolving capabilities of RA, PC, SA fibres in the finger pads of macaque monkeys. Johnson and Lamb's finding was that only SA fibres resolved the dot patterns in a recognizable form. In spite of this finding the authors were at some pains to leave open the question of the contribution of RA fibres in discriminating spatial patterns. However it is worth noting that in this study no distinction is made between SA1 and SA11 fibres and in fact the performance of SA fibres, presumably of both types, was reported as homogeneous. This is a surprising result, bearing in mind the different response characteristics of the two receptor types, one, the SA1, characterized by small receptive fields with distinct borders, SA11 by large size receptive fields with indistinct borders. The SA 1 fibres' small, well defined receptive fields, their static firing capability plus a relatively high density of innervation of the finger tip make their involvement in resolution of tactile patterns a very reasonable assumption. The SA11 fibres, however, have large, indistinct receptive fields and on this account may be assumed to have little resolving power. RA fibres have small receptive fields and fire only at the onset and release of pressure of pressure on the skin surface and appear to be relevant to the sensing of the edges of a stimulus object.

At the same time it needs to be kept in mind that all four of the mechanoreceptors identified by Vallbo and Johansson do in fact generate action potentials in response to punctate stimuli and this means that the brain has access to a number of alternative sources of information which it can use to check features of a tactile stimulus (e.g. for precise definition RA or alternatively SA 1 fibres) or can use them additively where a stimulus elicits a weak response from a single set of receptors ( e.g. RA plus PC fibres). Thus it may be inferred that the brain either uses and integrates information from all of the multiple receptor sources or alternatively and acting within the demand characteristics of the situation, may attend only to input from those afferent neural impulses which can supply information specific to the task in hand, ignoring input from receptors lacking this particular information content.

Since the different receptor systems are engaged more or less simultaneously once the skin surface makes contact with the stimulus it is plain that separate features of the stimulus pattern are communicated to the central nervous system along different parallel neural pathways. Pacinian receptors, for example, have receptive fields which are too large for fine discrimination but are sensitive to rapid changes of pressure and may contribute to a recognition of dot number. The SA11 receptors appear

to signal skin stretch and again are a likely source of information concerning area of deformation of skin surface making contact with raised dots.

As between RA and SA1 receptors, both with small, well-defined receptive fields, but RA receptors sensitive to quick changes of pressure but not to sustained pressure on the skin, the SA1 receptors sensitive to static pressure but not to quick changes, it would appear RA fibres will be most effective in distinguishing successively presented dots, SA1 fibres dots which are presented simultaneously.

In summary, the present imperfect understanding of the characteristics and function of the receptor groups in the distal finger pad is such that it is not possible to discard any one system as a non-contributor in identification of braille codes. However it seems likely that in identification of a tactile dot pattern the contribution of different fibres may be as follows: PC and SA 11 (large ill-defined receptive fields) signal the presence of a stimulus pattern and provide an estimate of its size (in the case of punctate stimuli such as braille characters, an estimate of the number of dots) and possibly also give a rough indication of the position of the stimulus on the finger pad surface, RA and SA 1 (small well-defined receptive fields) define the boundaries of stimulus features and give more precise information on their spatial location relative to the skin surface.

The above account of receptor function does not add a great deal to our understanding of the mechanisms mediating the experience of tactile perception and unfortunately, as the following section of the report shows, the present state of research on coding and cortical processes is only marginally more helpful in this regard.

### 3.2 Cortical Processing of Tactile Sensory Information

The properties of the cutaneous receptors themselves, as far as can be judged in the present state of knowledge, are such as to impose a severe limitation on the amount of information which can be taken up by the peripheral afferents in a unit of time and hence also on the speed at which cutaneous codes can be identified. While it is true, as Quilliam (1978) comments that: "....at present it is not possible to associate the conscious perception of any specific modality of sensation with the activation of a particular histological type of cutaneous receptor" , there is sufficient evidence that the cutaneous receptors taken as a group do have relatively limited discriminative capability and a slow reaction time and

in examining cortical processes it is necessary to bear in mind the relatively imprecise nature of the tactile sensory data which reaches the somatosensory areas of the brain.

Looking first at the problem of defining strategies of neural coding at afferent peripheral level, this understandably suffers from the difficulty of assigning function to the different receptor types, and it is not surprising therefore that much comment takes the form of conjecture rather than reliable evidence. Sherrick and Craig's conjectures (1982) are typical e.g. that activity patterns of peripheral nerves are preserved by some fibres in the CNS, that other fibres respond only to the onset of activity, others are inhibited by the input signals and still others respond only when peripheral nerves fire together , none of which surmises unfortunately, in the present state of knowledge, can be put to experimental test. In fact Nafe's conjecture as far back as1929 that the neural fibres serve receptor cells in differing combinations depending on the nature of the stimulus applied to the cutaneous tissue , currently has as much support as any other view.

As far as cortical processing is concerned, investigations using animals, mainly monkeys, does provide some indications of processes by which tactile sensory data is selected and integrated into perceptual wholes. The series of neurophysiological studies summarized by Sakata and Iwamura (1978) provide evidence of feature detection neurones in the somatosensory cortex. One type of cell, for example, fires in response to directional movement of the stimulus along the skin surface but not to punctate stimulation using a glass rod.

The authors conjecture that direction of movement of the stimulus may be as basic to tactile perception as contour is to visual perception. Unlike the visual system, integration of simple sensory information is not carried out in the primary projection area and in fact there appears to be point to point representation of the peripheral receptor sheets in the cortical neurones. Many neurones in the cortex were found to be correlated with one receptor type, e.g. Meissner corpuscles, Merkel discs.

What these findings suggest is that compared to cortical processing of visual and perhaps auditory information, the tactile system is poorly developed, with a much smaller repertoire of stimulus features with which to define a stimulus object. In evolutionary terms this state of affairs is understandable since, once established, the finer discriminations and the

greater range of defining qualities provided by the visual and auditory systems offered the much greater utility in dealing with a complex environment, reducing the need for dependence on the more blunt sensitivities of touch.

Evolutionary development of tactile perception, however, appears to have proceeded in stages and to have become established at different levels of sensitivity to environmental events before yielding priority of management of the organism to other sense modalities. The English physiologist H. Head in the 1940's hypothesized an older and more primitive stage which he termed "protopathic" in which the afferent neural system is capable only of gross, undifferentiated responses, and in evolutionary terms a more recent, "epicritic", stage mediating finer, more delicate discriminations of cutaneous stimuli. Mountcastle subsequently correlated Head's two stages with the spinothalamic and lemniscal systems and Werner in a paper published in 1974 summarizing findings of earlier neurophysiological studies, further hypothesized that the lemniscal system is specialized by evolution for active touch in contrast to passive touch, attributed to the spinothalamic system. Since the lateral lemniscus is generally considered to carry fibres of the auditory system and only the medial lemniscus is associated with somatosensory fibres, the functions of these two systems may, however, be more complex than Werner's analysis would suggest.

However the notion of independent systems mediating the transmission of tactile sensory information to the brain has relevance to the present research and will be elaborated on in the discussion of results. Briefly, these results carry an implication that afferent fibres conduct information about stimulus mass, or in the context of the present research, dot number, along different pathways from information relating to location of elements of the stimulus.

The above review of the tactile neurophysiological structure does not clarify any of the specific problems involved in the reading of braille but it highlights two features of the system - the complex nature of the receptor network serving the skin senses and the limited processing capability of the somatosensory cortex. A possible implication of these two pieces of information is that poor discriminative capability of the tactile system may be as much or more a result of limited processing resources of the tactile cortex as of failure of receptors to pick up fine detail. Some of the results in the present study do in fact point in this direction. Whatever the reason for discriminative shortcomings there are clearly substantial

difficulties attending any attempt to devise a high grade system of communication based on the skin senses.

Apart from the inherent limitations of the tactile neural system the braille matrix itself sets limits on the speed and accuracy with which the codes can be read. In the following section of the report, a review of studies of braille reading practices plus some more general comment on psychophysical matters pertaining to information transfer by means of the skin senses, will complete the account of factors recognized as impeding the development of better braille reading speeds.

## 4. THE BRAILLE MATRIX AND PROBLEMS OF CUTANEOUS COMMUNICATION

In studies discussed in the following sections, where reference is made to the braille code a standard terminology is used and it will be useful to preface these discussions with a definition of the most common usages.

The "cell" is the conventional term used in describing the 3-row 2-column matrix and this usage is followed in most research papers. This is however not the normal usage of the term and to avoid confusion in this report , where it is used "cell" will be taken to mean a single position within the braille matrix.

With the exception of substitution of "matrix" for "cell" other terms will be used according to conventional braille usage. Thus " braille character" will be used to refer to any of the 63 different combinations of dots within the matrix designating letters, punctuation marks and contractions. The word "dot" will be used to refer to the presence of a protuberance in any of the six positions of the matrix and lower matrix characters to those with no dots in positions 1 and 2 of the braille matrix , upper matrix characters to those with no dots in positions 5 and 6 (see matrix illustration page 1 above ). Whole matrix characters refer to those with a dot in all three rows of the cell.

Other conventional usages are Grade 1 braille for the uncontracted form of the braille system , Grade 2 for the contracted form adopted in more recent years in which single characters stand for whole or part words. For "cells" within the matrix in which a dot appears there

appears to be no agreed terminology and in the absence of a standard usage the following discussions will continue the practice adopted above of using the word "position" to refer to single elements of the matrix whether or not they contain a dot. The term "region" will be used to refer to an area of the matrix consisting of two or more adjacent "positions".

A useful point of departure in this section of the review is a comment by Geldard in his chairman's opening address to a 1973 conference on cutaneous communication systems , as follows : "...... there is no universal set of parameters to which all cutaneous communication problems can be referred " (1974). The comment may be taken as a paradigm of the problem of braille reading difficulties since the intent in the case of braille or other cutaneous data transfer system is matching of codes from a non-cutaneous modality (visual or auditory) which relies on a largely invariant set of parameters , with codes based on the discriminative sensitivities of cutaneous tissue in which both the sensory input as well as the mechanisms for processing it are potentially variable over a range of stimulus situations. Processing variability in the case of cutaneous codes results from the complexity of the receptor signalling systems , involving separate neural pathways operating in variable combinations , while the recent literature on touch testifies to the as yet imperfectly understood character of the sensory experience itself in which the contribution of down pressure, lateral shearing pressure, vibratory excitation as well as the proprioceptive stimuli are still to be properly defined. Geldard's point seems to be well taken.

Drawing the line between the purely physical and on the other hand, the perceptual or cognitive aspects of the braille problem is not always a simple matter. At the level of mechanical manipulation of the receptor surfaces , however, an obvious and serious obstacle to quicker reading by touch is the dependence on movements of the hands which , in normal reading of braille , are quite clearly incapable of matching the rapidity of the saccadic movements of the eye in traversing a line of print. It is difficult to put a value on this feature in accounting for slow reading speeds but it is plainly an important limiting factor. How important will depend in some degree on how the braille reader uses the fingers in following a row of braille print.

Eatman ( Foulke p. 173) using motion pictures established that the great majority of readers use only the index fingers and this is now accepted as a matter of common observation. It is also accepted by most writers that readers using both index fingers read faster than those using

only one finger (Fertsch1947) though Bliss ( 1978) claims it is "... common impression of braille teachers that braille readers who feel the embossed characters with more than one finger at a time read no faster as a group than single finger braille readers." It is perhaps symptomatic of the primitive state of current research on braille reading practices that a question as basic as this can still be referred for decision to hearsay evidence.

Fertsch's research on use of the two hands in braille reading appears to be the only systematic and methodologically sound investigation of this question ; earlier studies which she quotes (Grasemann ; Burklen ; Holland) suffer from problems of sample selection. Fertsch classified her subjects into three groups, those she terms 'right dominant' where the right hand is more effective than the left, ' left dominant' where the left hand is more effective than the right and 'hands equal' where the hands are equally effective in perceiving braille. What she found, in summary, is that subjects with 'hands equal' in normal reading , read faster than either of the other two groups, read a larger number of braille cells with the hands functioning independently and also as a group included fewer poor readers. Readers who were right dominant were nearly as effective as the "hands equal" group and were significantly superior to the left dominant group.

Fertsch's paper has little to say about the function of the two hands. On this subject Kusajima' monograph (1974) is more enlightening. Summarizing research the author conducted over a period of 35 years, the paper examines practices of good and poor braille readers based on recordings of the patterns of movement of the fingers as they traverse lines of printed braille. His observations indicate that the reading finger is "merely accompanied " by the other, controlling, finger but supplies what Kusajima describes as something akin to "indirect vision", that is it tracks what the reading finger has already covered and holds at points where text is lost, allowing the reading finger to relocate quickly to pick up the lost meaning. The controlling finger accordingly allows for a double tactual field as well as locating the beginning of the next line while the reading finger finishes the previous one. Good readers , he found , are characterized by few "zig-zag, up-and-down, or fluttering movements, (by) uniform pressure of the finger on the page, no regressive movements, and well-adjusted movements between lines with the help of both hands -- combined with a deep and accurate understanding of the meaning of the text. " Poor readers show deficiencies in one or more of these characteristics.

Kusajima's comments carry the inference that central nervous processing is capable of integrating information from the two fingers, but he provides no empirical evidence to support this conclusion. Confirmation is , however, supplied by Lappin and Foulke's experiments on multi-finger perception (1973) in which it is demonstrated that the two index fingers are more effective than any one finger. Lappin and Foulke's work also indicates that adjacent fingers on the one hand possess no advantage over a single finger, leading to the interesting speculation that fingers on the same hand compete for neural pathways while fingers from different hands take advantage of the independent function of the two cerebral hemispheres.

So far the discussion has been concerned principally with limitations imposed by hand and finger movement in tracking the braille script. A further impediment to braille reading speed is the relative slowness of the receptor system involved in the transduction of mechanical energy into neural excitations necessary for the register of sensory experience. An estimate by Békésy (1955) of the time for full development of sensation after the onset of a stimulus , for example , is 0.18 seconds for the ear and 1.2 seconds for the skin Similarly he found that the difference limen for auditory frequency discrimination is optimally of the order of 0.2 % but for the skin vibratory system does not fall below 5% to 10%.

Gescheider (1974) comments in this same connection that fusion of cutaneous sensation is lost when the time interval between stimuli is greater than 8-10 msecs while the corresponding interval for auditory clicks is 1.5-2.0 msecs. Gescheider explains this difference as due to differences in the cutaneous and auditory CNS since Uttal has reported that separate neural responses could be identified for pairs of electrical stimuli separated by as little as 2 or 3 msecs while subjects could feel the individual stimuli only when they were separated by 10 msecs or more.

The relatively poor temporal resolution Békésy and Gescheider refer to is matched by limited spatial resolution. A great deal of the earlier research on this subject, however, has been concerned with establishing the 2-point limen and the properties of receptors involved in discriminative judgements. Little of this research is of direct relevance to the present discussion but it is of interest to look at estimates of the two-point limen and error of localization made by Weinstein, matched against the dimension of the braille cell (Sherrick and Craig p. 67)

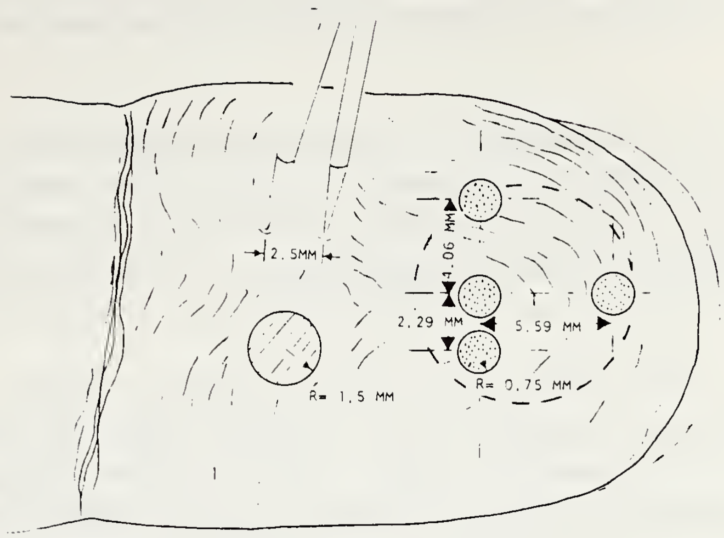



Figure 2.5. The size of the two-point limen and the error of localization on the palmar side of the index finger. Data are from Weinstein (1968). The size of the circle for the error of localization is based on the mean estimated error as described in the text. For comparison, standard braille dots are shown to scale, with the diameter of a single dot given at its base. Other dimensions shown are, in order of increasing size, the interdot, intercell, and interline distances. Values are from Nolan and Kederis (1969, p. 5). The large dashed circle around the dots represents the area covered by the vibrator used in obtaining the curve of Figure 2.3.

The error of localization shown in the diagram is a measure of the average furthest distance from an initial touch at which a second touch is judged incorrectly as being in the same locus. Two things worth noting are firstly that the error of localization is smaller than the discriminative limen and secondly that the diameter of the braille dot is also smaller than both the limen and the error of localization. The intercell and interline distances are greater than both the limen and the error of localization but it is notable that the distance between adjacent dots in a cell , in addition to the diameter of the braille dot itself already mentioned, is smaller than

each acuity measurement , which must give rise to some doubt regarding the correctness of choice of the dot and intracell dimensions. If these comparisons are taken at face value it seems certain that a dot lying at the periphery of the circle for error of localization of another dot will be perceived as separate from the first in only approximately fifty per cent of cases.

The frequent misperception of cell contents which will be referred to later in this paper may result from confusions ensuing from physical limitation of the receptor system illustrated by these comparisons. If this is the case there is a compelling argument for reexamination of the question as to which dot and cell dimensions are optimally discriminable.

Meyers, Ethington, and Ashcroft (1958) claim to have established that braille legibility is only moderately reduced when the interdot space is reduced to .080 inches ( 1.9 mm ) but the experimental procedure , based on reading speed over varying combinations of interdot, intercell and interline values was questionable and results were undoubtedly biased in favour of existing spacing specifications which subjects in the study were familiar with. In spite of a familiarity bias it is noteworthy that in the last of four test sessions, when the bias might be expected to diminish as a result of practice and increasing familiarity with the non-standard cell sizes , the above standard .100 inch interdot difference gave a substantial lift in reading rate. Accordingly, on the evidence of this research, the question of optimal values for interdot, intercell and interline distances cannot be considered settled, and as far as the present writer can determine there has been no later investigation which has produced more conclusive evidence on the matter.

The above discussions serve to illustrate general limitations of the receptor systems vis-a -vis braille codes. It is clear that a receptor system which is responsive to mechanical forces, that is to the presence or absence of a stimulus on the sensory surface, rather than to the variable high frequency wave stimuli which act on the visual and auditory systems, will have a much reduced capacity to pick up information in unit time and accordingly a much slower reactivity to stimuli. At the same time the fact that differences in speed of reading by means of touch ( braille ) and by vibratory impulses ( Optacon, Vibratese ) are minimal ( Craig and Sherrick 1982) appear to imply that limiting factors are not confined solely to the mechanical process in information transfer but also involve operations conducted at cortical level.

To complete this part of the review , a summary of the views

presented in a paper by Kirman (1973) will give some of the flavour of comment on the potential for communication by means of the skin senses. Kirman is primarily interested in the communication of speech patterns but his comments on braille and its limitations are of more than passing interest for the present project.

One limitation of braille as a system , as Kirman sees it , is that it relies on a small matrix of points to supply the variety of patterned information which the skin is required to interpret. He observes that :

> Tactile displays have been designed which rely on the observer's ability to detect each element in its particular locus rather than on his capacity to organize such elements into perceptual structures.
> ( page 65 )

He is concerned that accurate communication relies on detection of every element in a display and quotes from a paper by Selfridge (Kirman page 65) to make his point :

> the usual case of visual pattern recognition involves thousands of millions of bits. It is not just a case then of a few fixed elements, but the recognition of complex variable patterns of thousands or millions of elements. In the patterns of many of them, some can be altered without changing the pattern, while to change one of the elements in a braille character is to change the character absolutely and unequivocally.

He quotes from White et al. on this same point :

> The perceptual systems of living organisms are the most remarkable information-reduction machines known . They are not seriously embarassed in situations where an enormous proportion of the input must be filtered out or ignored, but they are invariably handicapped when the input is drastically curtailed or artificially encoded.
>
> (page 64)

It is apparent from these comments that Kirman's thinking on perceptual matters has a good deal in common with the views of J.J.Gibson and before him of David Katz , and centres on the idea of the apprehension of patterns as a matter of direct perception , rather than by way of integration of elements. The argument between these two points of view appears an empty one but for the present project it does bring into focus the importance of tactile sensitivity in the recognition of braille script, since, as Selfridge above points out , the loss of a single dot in a braille character changes the whole meaning of the character.

The loss may or may not be critical , depending on the context , but even if context is able to supply the lost meaning , the lack of redundancy still appears to be a significant shortcoming of the braille system. It is also a strong argument in favour of a modification of the system aimed at taking full advantage of whatever differential tactile acuities may exist in respect of individual positions or regions of the braille matrix as well as of the objective differentials discussed earlier in this document.

## 5. RESEARCH ON PERCEPTUAL CHARACTERISTICS OF THE BRAILLE CODE

Studies on the detection and legibility of braille codes are not extensive. Of relatively recent date the one series of studies which examines the subject systematically and in some detail is that conducted by Nolan and Kederis (1969). Prior to these studies , experiments by the Uniform Type Committee in the U.S.A. (1915) to test the relative merits of several different punctographic systems in use early in the present century, were the only published source of information on the speed and ease of identification of different dot configurations. Following the Nolan and Kederis studies Foulke and his students at the University of Louisville conducted research using modifications of the Nolan and Kederis experimental apparatus , and besides replicating a number of the earlier studies made some attempt to fill in gaps in understanding the perceptual and cognitive processes involved in reading braille.

Apart from these three sets of studies , experiments conducted by Millar (1974) using a dot-cell system to investigate how shapes are coded in memory by active touch , offer some insight into perceptual factors involved in sensing of dot patterns. The following review will be restricted to these four groups of studies. A number of other studies have some degree of relevance to the present research plan ( e.g. those by Burklen ; Horbach ; Ashcroft ; Pick, Thomas and Pick), but either suffer from methodology faults (e.g. Burklen used nails hammered into pieces of wood to simulate braille dots) or simply repeat data from the major studies; for these reasons all are excluded from this review.

### 5.1 Early Research

An account of the major studies begins with the first in chronological order, that conducted early in the century by the Uniform Type Committee of the American Association of Workers for the Blind. Reports of the Uniform Type Committee were not available in local data sources and the following details are summarized from accounts provided in Nolan and Kederis and in Schiff and Foulke's source book "Tactual Perception" (1982).

The initial UTC research had as its object the measurement of the speed and accuracy with which braille characters can be identified. The procedure adopted in the research required 53 subjects to read aloud , as rapidly as possible , a total of 20 lists of 160 braille characters , each list consisting of a common standard of 25 non-test characters repeated four times plus 60 repetitions of the test character located haphazardly within the standard array. The reading of the lists was timed and errors recorded and differences between the lists were assumed to provide a measure of relative character legibility. The procedure was admittedly rough but the order of legibility of characters and inferences as to factors contributing to greater or lesser legibility have been substantially confirmed by later research using more precise measures , and it is therefore worth examining the main results of this investigation.

The first UTC study provided one key result , namely that the fewer the number of dots the more legible the character. A later UTC research project also examined the effect of the number of dots on the readability of letters and examined the effect of the same factor on word legibility. Results of this research confirmed the earlier finding and found also that time taken to read words increased with increases in the number of dots . Words containing whole-cell , part-word contractions , that is contractions with dots in all rows of the cell and making up only part of a word , were read in less time and with fewer errors than the same words in full spelling. Words containing lower-cell , part-word contractions , that is contractions with no dots in the upper row ( positions 1 and 2) and making up part of a word , were read in slightly less time but with more errors , than the same words in full spelling. Finally, lower-cell, whole word contractions required considerably more time and produced more errors than the words in full spelling.

In summary the latter study demonstrated that while whole-cell contractions facilitate the reading of braille characters , contractions lacking dots in the upper row of the braille cell retard the

reading of characters. This finding could be interpreted to mean a better tactile acuity for positions in the upper row of the braille cell but equally it could reflect a lesser frequency of dots in the lower two positions of the braille character contractions used in the word lists of the UTC experiments. Unfortunately a listing of words and contractions is not provided in either of the source documents summarizing UTC findings but the results of the research are of interest for the present research in that they do provide a first hint of diverse sensing reactions in different regions of the braille cell.

The UTC also analysed types of errors appearing in their various studies. The most common errors were those of alignment , both vertical and horizontal , that is an identification of a character having the same number and configuration of dots as the stimulus but reversed top to bottom or left to right respectively. Other common errors were missed dots , added dots , and apparently also instances in which the mirror image of the stimulus is sensed.

### 5.2 Nolan and Kederis

Nolan and Kederis' investigation of perceptual factors in braille reading (1969) consists of a series of nine individual studies, only the first three of which are of direct relevance in the present discussion.

The first study amounts to an extended replication of the UTC investigation of the legibility of of individual characters of the braille code. The research procedures used by Nolan and Kederis , however, enabled a determination of letter recognition times as indices of legibility , something which could not be established with any precision in the UTC investigation. Since this first study of Nolan and Kederis has particular relevance for the hypotheses under consideration in the present research plan , both its procedures and its results will be dealt with in some detail.

To provide recognition time data in this study Nolan and Kederis worked with a specially constructed apparatus, termed a tachistotactometer, which controlled the tactual exposure time for individual dot patterns. The patterns were embossed on seven slips of plasticized paper and each slip as required was placed on a platform elevated by solenoids. A tightly stretched metal membrane with holes in it corresponding to the dot positions of the cells in a line of braille print was held just above the platform and when the platform was elevated the dots on the sheet protruded through the holes in the membrane to the height of

a standard braille dot and remain exposed for the predetermined exposure time. Spacing between dots and height of dots exposed above the surface of the reading screen was approximately those considered standard by the American Printing House for the Blind. Exposure times ranged from .01 sec to 10 min in steps of .01 sec.

Stimulus materials used by Nolan and Kederis were 55 braille characters randomly ordered on the seven strips of plasticized paper, eight characters on six of the slips, seven on the seventh slip. Eight characters of the available 63 were not used ; these were characters with dot patterns formed only in the right hand column of the braille cell and used only in conjunction with other characters to form two-cell contractions and possessing no meaning standing alone.

The research task for subjects , all blind children with at least four years of experience in reading braille, was to make absolute identifications of each of the test characters. As subjects had extensive overlearning of the braille characters Nolan and Kederis could assume that the minimum time required to identify a dot pattern was a valid index of legibility. The criterion for recognition of a character was three correct identifications out of four successive exposures. To avoid use of position in a list as cue , when half the characters in a list had been identified to criterion, the remaining unidentified characters were presented haphazardly rather than successively. The exposure procedure is referred to as the method of minimal changes but is in effect an application of the method of limits using only the ascending series of presentations. To use the descending series as well would have been inappropriate since identification as well as detection of stimuli was required.

Results obtained in the study consisted of recognition times for the 55 stimulus characters plus , what is of particular interest for the present research planning , a listing of characters confused with the stimulus characters by at least 25 per cent of subjects. This listing indicates positions in the braille cell where dots have been missed or added , allowing analysis in the case of missed dots of cell regions where tactile acuity is possibly deficient.

Recognition times for the 26 letters of the alphabet taken from the full listing of characters are shown in Appendix 4 along with rank orderings of the same letters based on their objective differentiating properties , taken from the paper by Sutcliffe (1986). To allow easy comparison of items in the two lists , recognition times have also been rank ordered.

An inspection of the comparative rankings indicates that the relationship between the rank ordering based on objective differentiation and that based on the subjective criterion of recognition time , is not a close one ( Spearman r =.13 , p >.10 ). The absence of an obvious close correlation of the two sets of ranks does not of course mean objective differences between characters do not have a significant bearing on recognition time differences , but it is apparent that other variables are operative whose effect is to confound effects of objective differentiation. Some of these factors are identified in the analysis below. It is worth noting , however , that the letters "p" and "q", which are least well differentiated in objective terms , and have similar braille configurations , are among the five characters which subjects took longest to recognize ; "q" in fact has the highest recognition time of all 26 letters of the alphabet.

Nolan and Kederis provide a concise summary of the findings of this first study and those findings that are directly relevant to the present research plan are best presented verbatim from their summary :

> . The braille characters differed significantly in the mean time required for recognition.
>
> . Character recognition time is positively related to the number of dots in the character.
>
> . Within groups of characters having the same number of dots , those characters with dots most widely dispersed have the shortest recognition times.
>
> . Characters whose dots fall in the lower two rows of the braille cell require 55 per cent more time for recognition than identical characters whose dots fall in the top two rows.
>
> . Sixty per cent of the erroneous responses to the stimulus characters involved naming a character similar in shape to the stimulus.

. Missed dot errors were responsible for 86 per cent of the incorrect responses.

. Dots falling towards the bottom of the braille cell were missed more frequently than those falling at the top.

. The order of legibility of the characters was correlated ( r =.46 ) with the order of their frequency of occurrence in print.

The findings of most significance for the present investigation are those indicating a longer delay in recognizing characters with dots in the lower two rows and the higher percentage of missed dots in the lower row of the cell compared with the top row. The following tabulation gives details of the latter result :

| Dot Positions | Proportions of Missed Dots | Dot Positions | Proportions of Missed Dots |
|---|---|---|---|
| Top LH | .07 | Top RH | .10 |
| Mid LH | .17 | Mid RH | .17 |
| Low LH | .25 | Low RH | .24 |

Taken at face value these results suggest that tactile acuity is most distinct in the top positions of the braille cell and least evident in the bottom row positions , with acuity in the middle range occupying a position approximately midway between top and bottom for both left and right hand ranges of the cell. At the same time the left and right hand ranges overall show practically no difference though position 1 does appear to have a small advantage over its right hand counterpart.

While these results may reflect a relative order of acuity in the dot positions, other factors undoubtedly contribute to the differences. One factor cited by Nolan and Kederis seems likely to be of particular

significance. This is the probability of occurrence of elements of the braille code appearing in reading material of the blind. A study by Kederis et al. is quoted in which a frequency count was made of the number of occurrences of the 63 braille characters , and of the six braille dots by position in the cell. It was found in the case of dots that occurrence was disproportionate : the total for the top two dots was 29 per cent greater than the total for the bottom dots and the total for dots on the left hand side of the cell 30 per cent greater than on the right hand side. Additionally, the occurrence of a dot in position 1 was 92 per cent more frequent than in position 6.

A curious feature of these results is that while the disproportionate occurrence of dots in the top and bottom ranges of the cell is consistent with the missed dot results , a similar disproportion between the left and right hand ranges is not. While the Nolan and Kederis results offer no explanatory clues, it seems likely that the disadvantage suffered by right hand column dots due to lesser frequency of occurrence , might have been offset by cues available from the prior fixing of row positions in the left hand column. Dots in the left hand column , contacting the finger pad surface prior to the right hand column , would not of course have similar spatial referents.

The Nolan and Kederis results are often difficult to interpret because of their failure to separate responses for codes with differing numbers of dots. They do however provide a tabulation of recognition time analysed by dot number and this demonstrates the critical importance of the latter feature in determining ease of identification of braille codes:

| Number of dots in cell | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| Mean Recognition Time | .030 | .033 | .058 | .091 | .128 | .190 |

This result, reflecting the inverse relationship between ease of identification and the number of dots in a code, parallels results from the

UTC study and is also in line with findings of the present study.

Other factors cited by Nolan and Kederis as determining influences on recognition time are (1) the location of open space in the cell and (2) the size of space between dots. In their analysis of the first of these factors , characters were classified as having a greater space or opening at the top and/or left or, alternatively, bottom and/or right of the cell ; using this categorization , mean recognition times for the two groups of characters were calculated as 2.72 and 3.32 hundredths of a second respectively.

Evidence presented for the second factor is not as clear cut and Nolan and Kederis themselves admit the effect is not pure though there is some indication that characters with space between dots are more quickly recognized than those without space between dots. It appears , however , that there was a degree of arbitrariness in the allocation of characters to the two categories of "standard distance " (i.e no dots separated by an unfilled space ) and "greater distance" ( i.e. at least two dots in the cell separated by an unfilled space ) , and it is noted that more lower cell characters are included in the "standard distance" category. This factor may therefore be considered of questionable significance in the present set of results , though any effect it may have is explicable in terms of easier tactile sensing for more distributed dot patterns.

In summing up the study results Nolan and Kederis emphasize the complexity of the interactions of "the various factors which , within the confines of a 2 x 3 array , determine the legibility of braille characters". In noting the tendency of subjects to attend to the upper and left-hand portion of the braille cell and the tendency for lower cell characters to be of inferior legibilty , they suggest the operation of three determinants : (1) certain aspects of tactual perception , (2) the directional quality of reading braille , (3) probability features of braille as used to represent written English. The second of these factors is to all intents and purposes an aspect of the first since it implies simply the spatiotemporal character of the perceptual process in braille reading and the dependence of the process on a tactile memory buffer.

Of the major findings of the Nolan and Kederis study , the relationship between number of cell dots and recognition time can be tentatively explained as an effect of increasing information load on the

detection system. The progressively higher missed dot error rate as the point of contact between dot and skin surface moves from top row to bottom row of the cell could, at face value, be seen to reflect the higher concentration of receptors and hence greater sensitivity towards the tip of the finger pad , but Nolan and Kederis' explanation in terms of subjects' greater degree of familiarity with upper cell characters is the more plausible. The absence of a clear advantage for either the left or right hand edges of the cell has been briefly discussed above and will be referred to in analysis of results of the present investigation.

The second and third studies in the Nolan and Kederis series have less bearing on the present research than the first in the series and will be reviewed more briefly. The second study dealt with recognition times for words differing in length , familiarity and orthography (with and without contractions) and compared the recognition times for braille words with recognition times for individual characters making up the words. Subjects consisted of groups of slow and fast braille readers.

The results of main interest for our present purpose are those concerned with recognition times for individual characters , which provide an opportunity for comparison with Study 1 results. There is however a significant difference between the two studies in that the stimulus list consisted only of characters used in the word recognition part of the experiment which means that all characters representing punctuation marks and most contractions are excluded.

While letter recognition times overall are higher than in Study 1 ( presumably due to a procedural difference not detailed) the letter order is reasonably similar. The tendency for recognition times to increase with increases in the number of dots in a character is also repeated but the effect is not as clearly demonstrated as in Study 1. A significant departure from the Study 1 results , however , is found in the tabulation of numbers of missed dots in the six positions of the braille cell :

| Dot Positions | Proportions of Missed Dots | |
|---|---|---|
| | Fast Readers | Slow Readers |
| Top LH | .04 | .05 |
| Mid LH | .12 | .13 |
| Low LH | .14 | .14 |
| Top RH | .18 | .19 |
| Mid RH | .23 | .21 |
| Low RH | .29 | .27 |

In these results it will be observed the row effect noted in Study 1 is repeated , that is , fewer missed dot errors are made in the top row of the cell than in the botttom row , the middle range occupying an intermediate position. It is worth noting, however, that positions of the leading left hand edge compared with the right hand edge have a consistently lower missed dot rate , an effect which was not apparent in the Study 1 results ( see tabulation above ). Unfortunately Nolan and Kederis offer no comment on the difference and no details are supplied either of procedures or additional data which might give an indication of reasons for the disparity. On the information provided it appears most likely, however, that an explanation lies in the different sets of characters used in the two studies.

Nolan and Kederis' Study 3 contains only one result of interest for the present discusssion. This is a finding relating word recognition times to the number of dots per word. In Study 1 , it will be recalled , there was a strong connection between character recognition time and the number of dots in a code, a finding which was only weakly confirmed in Study 2 in which the range of stimulus characters was reduced from the 55 of the earlier study to a total of 32. In Study 3 an analysis of variance conducted on recognition times by dots per word gave a significant result but an inspection of mean values for the dot categories did not reveal a systematic variation in recognition thresholds as the number of dots per word changed. Nolan and Kederis put this apparent inconsistency down to uncontrolled variables such as the degree of distribution of dots within the word. The results from this study as well as from Study 2 do however

indicate that dot number is highly contingent in its effect and is most clearly demonstrable as a determinant of recognition time where the sampling of braille characters approximates most closely to the total population of all possible character configurations.

### 5.3 Foulkes and Associates

The remaining studies centrally relevant to the present project are those undertaken by Foulke's students at the University of Louisville in the early and late 1970's and described in Foulke's chapter of the publication "Tactual Perception" (1982). Foulke first points out some of the shortcomings of Nolan and Kederis' apparatus, primarily its mass and the distance the platform must be elevated to the display position, which effectively meant that it was not possible to adjust the mechanism for exposure times brief enough to determine thresholds for some of the characters ( the shortest recognition time obtained by Nolan and Kederis was .02 sec).

To overcome these difficulties an improved tachistotactometer was built in the University's Perceptual Alternatives Laboratory. This machine was limited to the display of only one character at a time, the characters being formed by metal pins, each controlled by its own solenoid and adjusted to rise above the display surface to the height of a standard braille dot. Because of the significant reduction in mass of the pin assembly and the distance pins travel to present a character, Foulke claims it was possible to provide briefer exposure times and hence to provide more accurate threshold values over the full range of characters.

Challman in 1978 used this apparatus to test out an hypothesis concerning the identification of braille characters. According to the reasoning behind this research, identification of a braille character consists of first, a perceptual operation to register an image of the stimulus pattern in short-term memory, which while it decays quickly, is available for further cognitive processing during a brief interval. This ensuing cognitive process " compares the image with

information stored in long-term memory and ...... assigns it to an appropriate category of functionally equivalent stimulus patterns and abstracts those inherent features common to all members of the category to which it belongs. " (Foulke p.182-183).

According to this account , Nolan and Kederis' minimum exposure time required to identify a character accounted for that fraction of the total time that was spent in registering an image of the stimulus pattern in short -term memory. It did not measure response latencies and so could not account for the time required for the remaining cognitive operations.

( This analysis of the identification process in the Nolan and Kederis experiment is of course open to question. The substantially longer time to identify a five dot character compared to a two dot character is assumed to reflect a difference in the duration of the operation needed to establish the respective short term images. The time differential could however, with equal likelihood, reflect other cognitive processes such as coding and analysis of the tactile impressions. There is no reason to expect that these processes all occur after withdrawal of the stimulus pattern from contact with the finger pad.)

Challman's assumption was that if identification times for characters had a low level of correlation with legibility thresholds as determined by Nolan and Kederis' recognition times , then it could be assumed that the reading rate of a braille reader " might be determined more by the time spent in identifying characters than by the time spent in registering stimulus patterns , because a registered pattern is not useful unless it has been identified ".

The procedure used by Challman provided for a voice activated timer to register time between start of exposure of the stimulus and start of verbal identification. The correlation with Nolan and Kederis' legibility times using the Spearman formula was only .30 which leads Foulke to the conclusion that " this low correlation makes it plausible that the time spent in identifying characters is more

predictive of reading rate than the time spent in registering stimulus patterns in short-term memory ".

An inspection of Challman's results indicates that low identification times are mainly recorded for letters and high identification times for contractions coding two or more letters, which conceivably served as the basis for Foulke's claim, though the longer time taken to identify contractions appears likely to be due as much to a difference in sub-vocal articulation response time as to a difference in cognitive processing time.

The assumptions on which the Challman experiment is based are highly questionable and the relevance of the study to the present research proposal is no more than to point up the difficulties attending the use of response latencies rather than threshold measurements or error counts. A study of the the times recorded in the study shows no clear picture of identification advantage for individual rows or columns of the braille matrix.

The Perceptual Alternatives Laboratory constructed another apparatus which allowed the passage of a tape embossed with braille characters under the finger of the braille reader. This was designed to overcome the objection levelled against the tachistotactometer that it allowed only passive contact between finger and character. A paper tape transport similar in operation to that used in a tape recorder is carried from a supply reel across the display surface to a takeup reel. Tape speed is controlled by a capstan driven by a DC motor capable of controlled speed over a wide range. Exposure times were calculated by computing for each tape speed the time required for a width of tape equivalent to one letter space (.064 cm) to pass a specified point on the finger tip.

Foulke mentions only one pilot study in which this machine was used ( Kilpatrick) and the results obtained provide no grounds for confidence in its operation. While Foulke claims a rank correlation with Nolan and Kederis' recognition times of 0.73, the fact that measurements varied only in the range 0.04 to 0.06 secs and that the

correlation calculation as a result involved a high proportion of tied ranks , makes this calculation meaningless.

### 5.4 Millar and Lederman

Millar has published a number of papers in the past ten years or so, most of which are concerned with the question of how shapes are coded in memory by active touch. A paper published in 1974 studied the effects of delay and of distractor task performance respectively on tactile recognition of familiar and nonsense shapes. The conclusion reached was that only delay , acting through trace decay, affected short term memory of nonsense shapes but that distractor tasks , both verbal and tactile, affected memory for familiarized shapes , acting , according to Millar , on a longer term memory trace. There was no evidence of modality- specific effects.

Both blind and sighted children were used in the experiments and a finding of especial interest was that the blind children were faster in carrying out the test tasks but made more errors. Millar attributes this to a difference in response strategy and suggests that for the blind person, sacrificing some accuracy for speed is more economical when dealing with relatively slow tactile inputs. This makes intuitive sense and may provide an explanation for the high rate of error in the studies by Nolan and Kederis discussed above , in which subjects were all blind readers of braille.

Later experiments conducted by Millar tested an hypothesis that braille letters are coded in terms of spatial features (1978) in line with a finding by Taylor that visual letters were coded using this criterion. In these experiments Millar used recognition latency as a dependent variable in a task requiring matching of same and different braille cell configurations. If the hypothesis had validity , she reasoned , the time taken to decide that two shapes are identical should vary with the number of spatial features which differentiate them. Also, if global features are recognized, identical pairs should be matched faster and it should not matter how many dots make up a shape. Three types of spatial change were used : 1. a change in one

location of the 3 x 2 matrix by omitting one dot in a given location. 2. change in two locations by omitting a dot in one location and adding one in a different location. 3. change in three locations by omitting dots in two locations and adding a third in a different location.

The results of these experiments provided no support for the hypothesis that braille letters are coded in terms of spatial features , either for matching of same or of different pairs. Following this study , since the number of different features did not appear to be related in any significant way to recognition time , Millar decided to take a single spatial feature - symmetricality - and test its relationship to recognition accuracy. She introduced in the same experiment the variable of "crowding" , i.e. the number of dots in the stimulus configurations ( five dots versus eight dots ), and used this as a second variable , along with symmetricality , in a factorial test procedure.

Results showed no more correct identifications for symmetric than for asymmetric pairs. The number of dots , referred to as a "crowding" variable , was, however , significantly related to performance , the five dot pairs being recognized with more accuracy than eight dot pairs , both when pairs were symmetric and when they were asymmetric. This latter result led Millar to conclude that successful coding of relatively unfamiliar small tactual dot patterns ( subjects in the latter experiments were blindfolded sighted children) depended on texture differences.

Millar's conclusions from this series of experiments were that spatial features were not the salient cues for successive discrimination or coding in memory of dot patterns of the type used in her experiments , that is configurations within the 3 x 2 braille cell in the first experiments and the 3 x 3 matrix of the second series. She felt that this finding was "not unduly surprising" since in exploring braille and similar small complex dot patterns with the first segment of the index finger , an invariant spatial reference permitting location or direction as up/down , right/ left , vertical , horizontal or oblique is not available.

In summary , Millar sees two modes of dealing with tactual information , one in which the information is coded verbally ( the shape is categorized and named) or in spatial terms , the other which does not permit either verbal or spatial coding, is held briefly in short term memory , and does not lend itself easily to "attentional demands" , e.g. retrieval and comparison in a discrimination task. The latter mode is seen as involving textural properties of the stimulus and although Millar feels the codes necessary to store such information tend to overload the system she can still claim that " at the same time , texture differences are not merely uncoded after-effects of the stimulation and......can be coded and used in memory".

Millar's findings and ponderings are at times a little hard to follow but she does attempt to locate her results within a theoretical frame which is a departure from the largely empirical emphasis of earlier research. Implications for the study of tactual acuity in the braille matrix are not encouraging. If the braille reader has difficulty sensing spatial characteristics then it can be expected that identification of the presence or absence of dots in particular spatial locations will be subject to a considerable degree of error. Nolan and Kederis' results did in fact illustrate this difficulty ; the error rate was high and while missed dots were the most frequent type of error , errors of alignment were also common.

Millar's finding that "crowding" ( number of dots in a pattern) is an important determinant of recognition , and her conjecture that unfamiliar patterns are initially held in short term memory as textures, also receive indirect support from Nolan and Kederis' results. Whether differences in the number of dots can be conceptualized as changes in texture is , however , open to question, e.g. does spatial distribution of dots contribute nothing to texture quality ?

Lederman (1982) gives qualified support to the view that braille , particularly among poor readers , is perceived as texture. She quotes some of her work on perceived roughness which showed that increasing finger force magnifies the sensation of roughness and

questions whether errors in reading braille are related to inability to maintain a steady finger force.

If these conjectures of Millar and Lederman have any substance the concept of tactual acuity in relation to the braille cell is a very complex matter indeed. If the dot pattern is familiar , spatial cues may be used in coding into memory (Millar) and acuity can then be identified with a sensitivity to location within the cell. If the pattern is unfamiliar the cues are more likely to be non-spatial , i.e. textural (Millar) and tactual acuity is then non-locational (responding to vibratory cues ?). If the cues are textural , a change in finger force will change the character of the perceived texture (Lederman) and affect accuracy of recognition of a pattern.

Against these conjectures we have some indications from Nolan and Kederis' work that certain regions of the braille cell are recognized with more accuracy than others which could fit into either a textural or a spatial explanation but equally might reflect nothing more than the operation of peripheral factors reflecting the manner in which the surface of the finger pad is applied to the stimulus rather than the differential sensitivities of receptors within the pad. Where then does this leave the question of tactile acuity ?

## 5.5 The Concept of Tactile Acuity

Putting the different pieces of evidence and conjecture together we can construct a tentative hypothesis that when the reader's finger traverses a braille character a variety of factors come into play each of which has different implications for pattern recognition and for the forms of tactual acuity on which recognition depends.

Accordingly , while the stimulus object is invariant , consisting of a small number of protuberant dot shapes on a surface , the stimulus which the finger actually contacts may be variable depending on the manner in which the finger is applied stimulus. This introduces a large degree of ambiguity into the definition of the

stimulus. Certain controls can be exercised in the experimental situation , such as use of apparatus to ensure some degree of uniformity in the positioning of the finger but if Millar's and Lederman's contentions are of any validity the amount of pressure exerted and the speed of passage of the braille cell under the finger will change the form of the stimulus. If these two variables are controlled then the character of the stimulus again is potentially subject to change since both variables are critical to the strategies of active touch on which accurate sensing depends.

In the case of braille it is likely therefore that while the complete character may be presented to the skin surface , some of the component dots will be lost , not because of insensitivity of the receptors as such , but simply as a result of imperfect contact between the character and the epidermal tissue. If we accept this possibility it must also be accepted that tactile acuity per se can be measured only at the level of the individual receptor or the individual peripheral nerve serving a receptor within its field.

Procedures to ensure that a stimulus object produces some degree of consistency of indentation on the pad of the finger can no doubt be devised but the available research evidence is that constraints on finger movement act as an impediment to active touch which in turn attenuates sensitivity in receptors making contact with the stimulus object. There is clearly no easy solution to the problem but it is worth noting that the problem is not unique to tests of tactile acuity.

All tests of acuity in all modalities are in some degree constrained by physical impediments intervening between stimulus object and receptors though the difficulty is probably most pronounced in the case of tests involving the skin senses. For this reason it is important to have an understanding of terms as used in the current experiment. For the purposes of this research acuity will be defined as the sensitivity to stimulus objects as encountered in the course of normal self-monitored contact with the stimulus surface with no imposed conditions of finger pressure or restriction of movement of the

finger pad within the sensing area of the experimental apparatus. This definition is adopted fully recognizing that there will be variability in the manner in which the stimulus object is sensed by different subjects and also by the same subject in respect of different stimulus objects. It is felt better to allow this degree of random variability than to introduce controls to standardize contact with the stimulus object at the expense of substantial interference with the subject's ability to discriminate under normal conditions of active touch.

## 6. RESEARCH AIMS

The above extended discussion of origins and background of the present research illustrates some of the complexities of the tactile perceptual system and the difficulties attending investigation of a single factor in isolation such as sensory acuity.

The Nolan and Kederis results demonstrate variability of findings depending on the set of braille characters used as experimental stimuli and the research by Foulke's associates give a further indication of different results when the stimulus characters are sensed as they move under the finger of the subject rather than by static contact as in the Nolan and Kederis experiment.

Millar's experiments provided evidence that the sensory data are only a basic reference. Thus her research using delay and distractor tasks as independent variables indicated that recognition of braille characters is not by direct transfer of information to a response centre in the brain but rather is mediated by inspection of a short term memory trace. Further she confirmed that the number of dots in a character, which she terms crowding, is a significant factor affecting ability to identify the character , denoting a limited capacity to conduct a complete analysis of the sensory data within certain time constraints and implying an analytic identification strategy. Again a finding that spatial features were not a significant cue in discrimination of braille dot arrangements lends no support to an hypothesis based on a single act of apprehension and in fact carries a strong suggestion of a

different type of process.

These findings are all consistent with a model of braille character identification in which the number of dots and their positions in the braille matrix are extracted from an examination of a sensory memory and reassembled to provide a form of response to the tactile stimulus object. In such a model the subject's tactile sensitivity is one among a number of factors determining the form of a response, e.g. evenness of contact between stimulus and skin surface, speed of analysing sensory memory, distracting influences during the analysis as well as inhibitory and facilitating effects of dots in adjoining row and column positions.

Consideration of these factors led to a modification of the original plan of the research. The original plan envisaged a fairly straightforward discrimination experiment using pairs of single dot or two dot row codes, half the pairs consisting of identical codes, the other half codes in which the dots are positioned in different rows. Subjects were to be asked to say whether the codes were the same or different, the test of discriminative acuity consisting of a comparison of errors for each of the three rows of the matrix.

Studies reviewed from the literature on touch, particularly those reporting same or similar recognition times for different small dot number braille characters , gave some indication that a simple discrimination experiment of this kind might run into difficulties. In the event a small pilot test showed the impracticality of the approach. Rather than a test of comparative acuity in different rows of the braille matrix the procedure resulted in a test of recognition of line continuity or discontinuity. Thus a paired sequence of same row dots was sensed as a line extension of the first dot ; similarly a sequence of different row dots was simply a break in the line extension. In both cases there was easy recognition of which was which. The result was an extremely low error rate for all row positions both for single dot and two dot row stimuli.

This small experiment pointed up the difficulty of devising

a discriminative test of acuity excluding variables peculiar to the experimental situation. The alternative of a static presentation of stimulus characters such as that used by Nolan and Kederis would have largely removed this problem but at a cost of loss of active touch contact with the stimulus object and a resultant reduced discriminative capability (the evidence favouring 'active' as against 'passive' touch is presented in articles in the volume entitled 'Active Touch' edited G. Gordon, 1978, see reference).

Apart from the problem of test administration it became apparent that a simple discrimination procedure would provide minimal additional information concerning interacting factors present in the normal braille reading situation. While evaluation of these factors is not critical to the main objectives of the experiment it was felt that the study would lack proper perspective if no account was taken of them.

The experimental plan adopted in view of these different considerations entailed use of the full repertoire of 63 braille codes, presented to subjects in a randomized sequence, the experimental task consisting of absolute identification of the number and position of dots in each code. Differential acuity analysis then would consist in a comparison of error rates for single dot and two dot row codes in different pairings, using the criterion of identification of dot number and possibly also of dot position. In addition to the test of acuity, patterns of error for these and other groups of codes - two dot codes with dots in vertical or horizontal arrangement plus three dot codes - might be expected to provide a basis for investigation of perceptual factors acting on the sensory data.

Consideration was given to inclusion in the analysis of data for all 63 braille code but dot arrangements in four and five dot codes made impossible the selection of pairs of codes to provide a satisfactory test of the main hypotheses and for this reason these codes along with the six dot code were excluded from the detailed analysis. They were included in the study therefore solely as buffers between codes used in the tests.

## 7. HYPOTHESES

The primary focus of the research was on the central issue of tactile acuity in different regions of the braille matrix though examination of perceptual factors, as indicated above , was included as a supplementary investigation.

Hypotheses concerning acuity can be stated in specific terms. Hypotheses to do with perceptual factors were not conceptualized in advance but the expectation was that they would emerge during a first analysis and then would be tested against other data in the course of more detailed analysis. This meant of course a testing of hypotheses against the data from which they are derived and to this extent the study of perceptual factors could be little more than descriptive in character.

At the same time the explanatory value of the hypothesized factor, particularly its apparent width of application over data from different parts of the study, would provide some indication of more general validity. A final test of validity rests with an experimental procedure involving proper controls and in the present analysis the principal aim will be simply to identify factors which help explain tactile acuity results , particularly those which run counter to an expectation of equivalence or difference of acuity in different regions of the finger skin surface.

The main research hypotheses are stated as follows:

(1) Tactile acuity is variable as between regions of the finger pad surface making contact with different row positions of the braille cell

(2) Positions in the left hand edge of the braille cell are sensed more easily and with greater accuracy than positions in the right hand edge.

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

The null hypotheses may be defined as follows:

(1) Tactile acuity is identical in the three rows of the braille matrix, and as corollary hypotheses : (i) mid-row acuity is not different from acuity in the top row , (ii) mid-row acuity is not different from acuity in the bottom row , (iii) top-row acuity is not different from bottom-row acuity.

(2) Tactile acuity in left and right hand columns of the braille matrix is identical.

## 8. EXPERIMENTAL APPARATUS

Apparatus for the experiment consisted of a tape transport system which allows the passage of Dymo tape 12mm in width (see Appendix 5 for example of tape) across a display surface on which the subject's finger can be positioned in such a way as to make effective contact with braille characters embossed on the tape. The display surface was enclosed in a metal frame across the front of which a cloth curtain is placed to eliminate visual identification of the characters while allowing the hand easy access to the surface. A shaped guard on the display surface enables the sensing finger to be held in a fixed vertical position eliminating movement of the finger pad . The mechanism was geared to run the tape at constant speed allowing a contact time of .25 second for the complete passage of a single character under the subject's finger.

The mechanism provides both manual stopping of the tape for use during subject training and automatic stopping for the experiment proper. Automatic stopping allows a pause of five seconds

following presentation of each braille character during which the subject records on a response pad the matrix positions of embossed dots which he or she senses.

Embossing of braille characters on tape was carried out by a staff member of the N.S.W branch of the Royal Blind Society. Equipment used for this purpose is standard for the Society but produces braille cells of different dimensions from those mentioned by Nolan and Kederis and by Foulke. Dot height was .5 mm , dot base diameter 1mm and vertical and horizontal dot separation 2.5 mm.

The response pad consisted of six keys of a printing calculator forming a 3 x 2 matrix simulating the positions of the braille matrix. Adhesive white paper dots were affixed to the six keys to conceal the numerals and all other keys were masked by a metal hood. ( See Appendix 5) for photographs illustrating the main features of the apparatus).

## 9. PROCEDURES

### 9.1 Training

A training session lasting about thirty minutes familiarized subjects with the form of the test and the procedures to be followed. This involved firstly an operation to ensure a correct positioning of the finger pad on the display area. For this purpose a series of filled braille characters ( all six positions of the matrix containing a raised dot ) was used. Different adjustments of the finger guard were tried until the subject signified that he or she had even contact with dots in all three rows of the matrix during passage of the tape under the finger pad.

Following this part of the training a random series of braille codes was presented to the finger pad and verbal responses checked to ensure that no systematic biases were present favouring

individual rows; where the subject appeared to be missing dots in a particular row or rows the initial exercise using the completely filled matrix was repeated. Finally, once it was decided that the subject was making consistently even contact with all three rows , the subject was given a trial run with a complete set of codes during which responses were recorded on the response pad. For the trial run the presentation of codes was started at a random point in the series to reduce the likelihood of learned effects

## 9.2 Test Proper

The test proper consisted of three presentations of the series of sixty three braille characters with a delay of three or four minutes between each complete presentation. The possibility of a learning effect resulting from use of the same sequence of codes was recognized but practical difficulties involved in use of three different orders of presentation precluded its use. Thus the use of a three tape reel providing three different random orders meant an increase in load on the mechanism which resulted in a significant start to end slowing of tape speed; the other alternative of using three tapes one at a time meant delays with tape changes which it was felt would seriously affect the quality of subject responses for tape presentations after the first series of codes. As it was the administration of the test took approximately one hour, probably a maximum beyond which subject concentration would be expected to weaken.

Fears of a learning effect were considerably allayed by a pretrial of the procedure. An inspection of subject protocols of the experiment proper also showed only minimal evidence of repeated response errors.

Nevertheless . to provide some measure of variability in order of presentation of characters two tapes with different random orders were prepared and each used for a half of the subject sample. The order of presentation of characters on the two tapes is shown in

the Appendix 6. A detailed check list of instructions for administration of the training session and test proper is provided in Appendix 7.

### 9.3 Sample Size

Two criteria were available to assess relative acuity in the three vertical regions of the braille matrix. These criteria were (1) the percentage of responses correctly identifying dot number and (2) the percentage of responses correctly identifying the position of dots. Identification of dot number was selected as the primary experimental measure since this response more directly reflects the firing or absence of firing of neural fibres in contact with protuberant dots. Identifying dot position by contrast is a more complex response involving both sensing of the presence of a dot and judgement of spatial relationships within the sensory field introducing in turn perceptual factors not related to sensitivity of the receptors. Identification of dot number , while not entirely free of the possible effects of confounding variables , for example those related to the recording of a response , is considered the best indicator of acuity available in an experiment of this kind.

Using this criterion of acuity , the problem of a testable difference between treatments ( treatments being defined as the three separate presentations of a row stimulus ) must be addressed. The Nolan and Kederis results presented above ( see page 27 above ) show that under the conditions of their experiment the incidence of missed dots in the three rows of the braille matrix was in the following proportions :

| | |
|---|---|
| Top Row | 17 % |
| Mid Row | 34 % |
| Low Row | 49% |

To test that a gradient in acuity exists between top and bottom row it appears therefore that a 2 : 1 difference in error rates

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

( or conversely correct response rate ) in identification of dot number for row stimuli would be sufficient to establish reliability of the experimental effect.

To estimate an appropriate sample size we can take as a starting point the range of responses available to the individual subject at each presentation of a stimulus character. Since there will be three presentations to the subject of each braille configuration the possible responses are a nil , one , two or three correct dot number identifications. This means that in a comparison of row responses , for example responses to the three single dot codes each with the dot in the same column but in a different row position , the smallest difference between rows for the individual subject is one dot number identification error , that is a 2 :1 difference between adjacent rows. This is in line approximately with the Nolan and Kederis results.

Using this difference criterion an estimate of likely variance for alternative mean error rates of one error and two errors per presentation was calculated ( this could have been two and three errors or nil and one error but one and two errors seemed a more likely outcome ). For this calculation two dummy samples of 50 'subjects' each were constructed from sets of random numbers adjusted to give the required mean error rates. Using these dummy values variances were calculated and tabulated in the form suggested by Winer ( 1971 - page 161 ).

| Treatment | Population Mean | Population Variance | Treatment Effect |
|---|---|---|---|
| 1 | 1 | 0.82 | -0.5 |
| 2 | 2 | 0.98 | +0.5 |

Based on these values a residual variance of 0.90 was calculated giving a phi value of 0.53 which on charts provided by Winer indicated a sample size of about 20 subjects per treatment to detect a mean difference of one error per three presentations of two stimulus characters with power of 0.90 and $\partial$=.05.

[illegible]

Converted to percentage terms this sample size should be adequate to establish that the difference between , say , a 33 percent and a 66 percent correct dot number identification for two row stimuli , is likely to be a real difference.

Target sample size for the present experiment , however , was set at 40 subjects with three presentations of stimuli per subject , giving a total of 120 responses per stimulus. The larger sample size and the repeated presentation of stimuli can be expected to provide a higher level of reliability and also scope for detection of smaller row differences if these are encountered.

### 9.4 Sample Composition

The nature of the experiment , consisting in a test of relative acuity in different regions of the finger pad , precluded the use of subjects who had experience in reading braille characters and who would be likely as a result to bring to bear on the identification task biases related to varying degrees of familiarity with codes representing letters of the alphabet. Subjects used in the testing were accordingly screened to ensure that none had specific acquaintance with the braille set of codes.

As a matter of convenience subjects were drawn from among first year Psychology students and as a result the majority were aged 18 to19 years though a minority were either slightly younger or slightly older , the full range being from 17 to 24 years.

The population from which the sample was drawn is therefore very tightly defined in terms of age , educational standard and braille experience. A similar degree of homogeneity may be expected to exist in respect of tactile sensitivity and response capability. These characteristics are however probably important only insofar as they affect the general level of accurate identification. In terms of relative acuity in different regions of the finger pad populations are likely to be approximately equivalent unless there is a biased

[illegible]

distribution of injury or abnormality in particular areas of the pad. Subjects in the present experiment were screened accordingly and those with recent cuts or sores on the skin surface excluded from the sample.

The sample used in the experiment consisted of 13 males and 24 females , providing a total of 37 subjects. This was in excess of the sample size of approximately 20 subjects needed to test the specified response differences discussed above and only slightly less than the 40 subjects targeted for checking other non-specified experimental effects. The disparity between male and female subject numbers was not of especial concern since this bias , as discussed above , could on the worst assumption affect only the general level of response and not the relative acuities of different regions of the finger pad.

## 10. RESULTS : ANALYSIS AND DISCUSSION

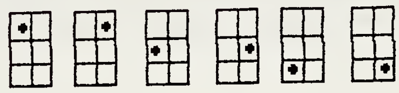
### General Plan of Analysis

The following sections of the report are restricted to an analysis of data for one, two and three dot characters. Four, five and six dot characters because of relatively complex dot structures do not lend themselves as readily to manipulation needed to test the main hypotheses or to generate other hypotheses bearing on questions of perceptual distortion and for this reason are excluded from the analysis.

The presentation of results for one, two and three dot braille characters is provided in two sections. The first section is devoted to a discussion of the significance of the results in relation to the main hypotheses under test. A separate analysis then examines aspects of the data which allow inferences regarding more general features of the braille identification process.

## 10.1 Test of Differential Sensitivity Hypotheses

### 10.11 One Dot Braille Characters



1 2 3 4 5 6

(numbers are used to designate codes in following analysis)

TABLE 1

ONE DOT CHARACTERS : CORRECT DOT NUMBER RESPONSES

| | | DOT NUMBER CORRECTLY IDENTIFIED % ( Base : 110 presentations of stimulus N=37 subjects ) |
|---|---|---|
| | 1 | 82 |
| SINGLE | 2 | 77 |
| | 3 | 80 |
| DOT | 4 | 88 |
| | 5 | 85 |
| STIMULUS | 6 | 88 |

The above results show that identification of correct dot number for one dot braille characters is achieved with a high degree of accuracy for all six positions of the matrix. The range of error is 23 percent for the top back edge cell to 12 percent in the case of the middle and bottom cells of the matrix. The small amount of error in all dot positions obviously restricts the base on which a finding of relative positional acuities can be made and if a conclusion were to be drawn from the above results it would indicate a more pronounced sensitivity in the finger surface contacting the lower row positions of the matrix and a somewhat lesser sensitivity in the area of the skin nearer the finger tip ( see Statistical Appendix 1 for significance test calculation ).

Such a conclusion however is questionable bearing in mind not only the small amount of identification error in all cell positions but also evidence from histological studies indicating a density of receptors of all types at least as great in the finger tip as in the skin surface further away from the tip ( see discussion page 10 above ).

[illegible]

The one important conclusion that can be drawn from the one dot results is that under the conditions of the experiment subjects are able to achieve a high degree of accuracy in detecting and identifying this type of stimulus. For the purpose of testing the differential sensitivity hypotheses however the results are of limited value and for a more effective test it is necessary to look at responses to the three two dot characters consisting of sequential dots forming a row in each of the three horizontal positions of the braille matrix.

Before presenting a tabulation of row responses it will give point to the following analysis to restate briefly reasons for using correct identification of dot number as the main criterion of regional differences in tactile acuity ( the rationale is discussed more fully under <u>Research Aims</u> in an earlier section of the report ).

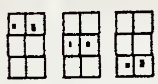
The dot number response consists in the detection of the number of protuberances impacting on the finger pad surface without regard to their position in the braille matrix. This requires only the registering of the simple event of separated receptor firings as the dot passes across the skin surface and is therefore a relatively "pure" reflection of regional sensitivity within the area of the finger pad corresponding to row positions of the matrix.

The alternative measure which might be applied to test of acuity is a count of correct positioning responses for dots in different row positions of the braille matrix , that is comparison of the number of responses assigning dots to their correct row position in the matrix. This measure however has serious problems as a criterion of relative acuity since in addition to the judgement of dot number it takes into account decisions made by the subject concerning the boundaries of the matrix and the spatial relationships of the dot to these implicit markers , judgemental factors which are extraneous to the central issue of regional sensitivy of receptors.

Dot positioning results for this reason have very little value as criteria of tactile acuity though as later sections of the report illustrate they provide a particularly useful basis for investigation of the perceptual processes involved in identification of braille dot patterns. Dot number identification on the other hand is not dependent on spatial judgements and for the purposes of the present investigation appears to have no serious problems as a criterion for test of the acuity hypotheses.

Using the measure of dot number identification the following analysis examines the error rates for responses to two dot configurations in which either top, middle or bottom row cells are filled, the other four cells in each case being unfilled. Position responses are also shown as part of the complete tabulation but as discussed above have no bearing on test of the main hypotheses.

## 10.12 Row Stimuli



R1 R2 R3

For convenience of reference the row stimuli are labelled as above, R1 for top row, R2 for middle row and R3 for lower row. Summarized results for this group of stimuli are as follows:

TABLE 2

TWO DOT HORIZONTAL BRAILLE CHARACTERS

( Base : 110 Presentations of each stimulus N=37 subjects )

| | | R1 % | R2 % | R3 % | Total Row % | Other 2 Dot R's % | Total 2 Dot R's % |
|---|---|---|---|---|---|---|---|
| | R1 | 62 | 5 | - | 67 | 5 | 72 |
| Stimulus | R2 | 10 | 45 | 13 | 68 | 7 | 75 |
| | R3 | - | 35 | 26 | 61 | 6 | 67 |

The last column of results in Table 2 provides relevant data for test of the main hypotheses. The figures in this column are a total of all two dot responses comprising row responses shown in the fourth column plus other two dot responses - diagonal and vertical - shown in column 5.

The error rate for each row stimulus - 28 percent for stimulus R1, 25 percent for R2 and 33 percent for R3 - prima facie suggests only

minor differences in sensitivity between rows and a test of statistical significance (see Statistical Appendix 1 ) indicates a "p" value of around 0.7 and a high probability that the differences are substantially a result of sampling error.

The row results therefore clearly support the null hypothesis in respect of sensitivity in those regions of the finger pad in contact with rows of the braille matrix. Even if the small deficit in correct dot number identification in bottom row responses reflects a real difference in sensitivity relative to top and mid rows the difference on the evidence of the above results is quite small and of little significance for the reader of braille script.

It should be emphasized at this point that the research was set up to simulate as far as possible the situation of the braille reader in traversing a line of braille script. That is the presentation of the experimental stimuli exploited the advantages of "active touch" such that the stimulus character is moved under the subject's finger rather than being presented in "static" manner as , for example , in the Nolan and Kederis experiments reviewed above. Thus while the vertical dimension of the area in the finger pad surface making contact with rows of the braille matrix may be small enough in itself to limit the range of acuity differentiations , the mechanics of the "active touch" presentation offers a more plausible explanation for the absence of row acuity differentiation in the results discussed above. In this form of presentation , which is of course also similar to the braille user's mode of contact with braille script (the only difference is that whereas in the experiment the braille characters are moved under the subject's finger , in the braille reading situation the finger moves over the characters ) , the passage of the character across the surface of the finger pad causes the protuberant dot or dots to impinge on a succession of receptor regions so that what is communicated to the brain is not a single sensory impression but a train of impulses as the dots pass over successive regions of the finger surface. The width of finger pad traversed by dots in a braille character is roughly 12 mm to 15 mm depending on the size of the reader's finger which means that a dot with radius of approximately 0.5 mm will encounter a relatively large number of receptor zones of this dimension as it passes from one side of the finger pad to the other.

"Active touch" accordingly is able to deliver to the brain a considerable surplus of information, in contrast to the limited information supplied by a single contact between dot and skin surface in the case of static presentation. This surplus information , it may be plausibly argued ,

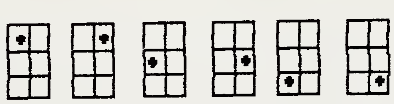
will do much to blur regional differences in acuity across row positions on the finger pad surface. Thus if there is imperfect register of a dot stimulus as it first makes contact with receptors , contacts with succeeding receptor zones allow additional opportunities for correct identification. Accordingly, if receptor systems at the three regions of the finger pad surface corresponding to rows of the braille matrix do in fact differ in sensitivity, the braille reader by virtue of movement of the reading finger across the braille script quite possibly is able to reduce the effect of errors of identification which occur with a single contact of the braille character with the skin surface.

In summary the two dot row results indicate that under conditions closely simulating the actual braille reading situation no differences in tactile acuity are apparent at regions of the finger pad surface corresponding to row positions of the braille matrix and the null hypotheses relative to receptor sensitivity in these positions are therefore supported.

## 10.2 Perceptual Processes in Braille Character Identification

In this part of the report dot positioning responses for one , two and three dot braille characters are examined and tentative hypotheses are offered relating to the role of non-sensory factors in identification of braille characters. For the purpose of convenient reference some of the tabulations in these sections repeat results included above in the discussion of dot number responses.

### 10.21 One Dot Braille Characters



1 2 3 4 5 6

(numbers are used to designate codes in following analysis)

The following section of the report analyses row positioning results for each of the single dot stimuli.

TABLE 3
ONE DOT CHARACTERS

( Base 110 presentations of stimulus N=37 subjects )

| | | Single dot Responses | | | | | |
|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 |
| | 1 | 49 | 17 | 9 | 5 | 2 | - |
| Single dot | 2 | 50 | 18 | 5 | 4 | - | - |
| Stimulus | 3 | 10 | 3 | 48 | 9 | 5 | 5 |
| Positions | 4 | 5 | 2 | 43 | 29 | 6 | 3 |
| | 5 | - | - | 19 | 7 | 48 | 11 |
| | 6 | 1 | 1 | 24 | 14 | 37 | 11 |

As a first observation it clear from the above results that subjects found the task of identifying the correct column of the dot - front edge or back edge - exceedingly difficult. Where the dot was located in the back edge - positions 2, 4 and 6 - there was a strong tendency to describe it as a front edge dot. The result is similar for all back edge row positions.

Row identification on the other hand is quite good indicating a general capability to establish cues defining braille matrix boundaries on the finger pad surface. Single dots in all three rows elicit a correct assignment of row position in more than 50 percent of presentations for all but position 6 (bottom row back edge) which has 48 percent correct row location. Row location results for all six positions may be summarized as follows ( percentage of correct dot number identifications is provided for comparison):

TABLE 4

ONE DOT CHARACTERS : CORRECT ROW POSITION RESPONSES

(Base 110 presentations of each stimulus N= 37 subjects)

| Dot Position | % Correct Row Responses | % Correct Dot Number Identification |
|---|---|---|
| 1 | 66 | 82 |
| 2 | 68 | 77 |
| 3 | 57 | 80 |
| 4 | 72 | 88 |
| 5 | 59 | 85 |
| 6 | 48 | 88 |

The result of special significance here is the 48 percent correct row response recorded for position 6. This result is substantially less than other back column results and looked at in association with the other bottom row result - 59 percent correct for position 5 - might prompt a suspicion that as far as row identification is concerned there may be a weaker sensing of lower positions of the braille matrix. Looking at all three combined row results - 67 percent for top row , 64 percent for mid row and 53 percent for bottom row there is a further suggestion of a gradient from top to bottom of the matrix.

This conclusion would have some plausibility if it were not for the disparity which exists between these results and dot number identification responses. Since, as discussed in the previous section of the report , dot number identification has much the better credentials as an accurate gauge of relative acuity , it can be assumed the disparity between row positioning results for bottom row dots compared with dots in the top and middle rows is a function of factors unrelated to regional skin sensitivities.

The data does not allow a precise specification of these factors but the nature of the skew in row position results suggests the following perceptual process. If the subject is uncertain as to the vertical or row location of the single dot a reaction which might be expected is reduction of the task to a simpler , two step , operation involving first an assignation of the dot to an upper or a lower region of the matrix which then allows a further judgement assigning the dot to the upper or lower part of that region. This strategy breaks the task of row identification into simpler units

but at the same time it introduces two levels in which error can occur and because it involves two separate judgements presumably also prolongs total identification time.

Error can arise first in this identification strategy when the subject, in deciding whether a dot is in the upper or lower region of the matrix, in effect imposes a subjective mid point or divider in order to separate these two regions. The subjective divider is not necessarily coincident with the objective mid point of the matrix and the experimental results showing a higher incidence of correct locations for single dots in the top and mid row indicate that in terms of this hypothesis a significant proportion of presentations elicit a response in which the subjective divider is off centre relative to the actual position of the mid row. Accordingly for any group of presentations of a single dot stimulus, positionings of the divider may be assumed to be distributed ( probably assymmetrically ) around a modal position located either above or below the true mid row position.

If it is now assumed that the subjective divider is variably distributed over a band centred not above but below the true mid row, the recognition sequence can be described as follows.

A single dot is registered and at the same time a judgement is made estimating the vertical boundaries of the braille matrix and , based on this estimate , a midpoint established dividing the matrix into upper and lower regions. The single dot is then tested for location in the upper or the lower region and for distance from the divider zone. Assuming that the divider is more likely to be positioned below than above the objective mid position, a top row stimulus dot will still, in most instances, be sensed as occupying a position above the divider and its vertical position correctly identified; it will be confused with the mid row when the divider is above the objective mid point and close to the top row position, but this will be an infrequent occurrence.

A mid row stimulus will mostly be sensed in or near the subjective divider zone since the latter is assumed to range above and below the objective mid point , but this stimulus will be subject to some error of confusion with the top row stimulus when the divider moves near an extreme position below the matrix mid point, and will also be confused with the bottom row when the divider moves similarly above the objective mid point.

A bottom row stimulus, when the subjective divider is located near the objective mid point of the matrix, will be identified correctly but since the modal position of the divider is assumed to be below the objective mid point, a dot in the bottom row will be subject to frequent confusion with the mid row. The probability of confusion of mid row stimulus with bottom row will be considerably less since the subjective divider is assumed to have a modal location just below the true mid row position and to be distributed in a range above and below this point.

Checking the one dot results against these assumptions, it will be noted ( Table 3 above) that in a total of 110 stimulus presentations for each of positions 1 and 2 , that is the top row positions , 66% and 68% of responses respectively identify the correct row, 14% and 9% identify the stimuli in a mid row position and 2% and nil percent respectively in a bottom row position.

For stimulus positions 3 and 4 - the mid row positions - , 57% and 72% of responses respectively identify the correct row while 13% and 7% assign the dots to the top row and 10% and 9% respectively to the bottom row.

In the case of bottom row stimuli 59% and 48% of responses identify the correct row for dots respectively in position 5 and 6, but 26% for position 5 and 38% for position 6 judge the dot to be located in the mid row. Confusion of dots in the bottom row with top row positions occurs in nil instances for a position 5 dot and in only 2% of presentations of the position 6 dot.

There appears therefore to be little discrepancy between the actual distribution of responses and the form of distribution indicated by the hypothesized identification model. This does not of course establish the validity of the model but it provides some measure of confidence in its explanatory value.

Leaving the question of formal validation on one side however the notion of a subjective midpoint and of a systematic tendency to locate it above or below the actual mid row position of the braille matrix makes intuitive sense. To assume otherwise would be to suppose an improbable degree of accuracy in subject's judgement of matrix boundaries on the finger pad surface. The tendency in the present set of results to locate below the true mid row may be an artifact of the experimental conditions and under different conditions the tendency might be to locate the

subjective mid point above the true mid row position. This can only be established by further research. It is plain however that the present experimental data is best explained on the assumption of a subjective midpoint located below the real centre of the matrix.

In the next section of the report perceptual factors affecting position identification of two dot braille configurations will be examined. In this discussion the main focus will be on the interaction of sensory memory and attentional resource. Arising from the discussion an analytical model of braille character identification is proposed.

### 10.22 Two Dot Braille Characters

The two dot stimuli consist of three horizontal or row sequences, top, middle and lower row; four vertical sequences with dots in adjacent rows, i.e. no interposed spaces between the two dots (<u>short verticals</u>); two verticals with dots in top and bottom rows, i.e. an empty position between the dots (<u>long verticals</u>); four diagonals consisting of dots in adjacent rows (<u>short diagonals</u>); two diagonals consisting of dots in top and bottom rows (<u>long diagonals</u>).

Results for each of these groups will be considered separately, but before proceeding to detailed analysis a tabulation summarizing responses to each group of stimuli will serve as a general framework in discussion of individual groups:

TABLE 5

TWO DOT BRAILLE CHARACTERS

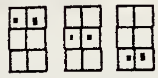
| Stimulus | Correct Identification: As 2 Dot Character | Correct Identification: By Orientation | Character Correctly Identified |
|---|---|---|---|
| (Base : 110 presentations of each stimulus N=37 subjects) | | | |
| | % | % | % |
| Horizontal (Row) | 70 | 65 | 44 |
| Short Vertical | 66 | 38 | 12 (26) |
| Short Diagonal | 50 | 20 | 12 |
| Long Vertical | 50 | 35 | 6 (14) |
| Long Diagonal | 36 | 23 | 13 |

(figures in brackets are percentage correct identification of vertical characters disregarding column error)

This tabulation illustrates the widely differing response rates for different positionings of two dots in the matrix. Identification as a two dot character ignoring orientation or position of dots is correct for 50 percent or more of presentations with the exception of dots forming a long diagonal. Recognizing the correct orientation of the two dots, - horizontal, vertical or diagonal - elicits a greater diversity of response. Horizontal ( row) characters achieve a correct orientation response in 65 percent of presentations but no other two dot character has a better than 38 percent correct response. Correct absolute identification within the braille matrix shows an even greater disparity between stimulus groups.

These differences will be considered in detail in the following sections of the report.

**Row Stimuli**



R1 R2 R3

For convenience of reference the row stimuli are labelled as above, R1 for top row, R2 for middle row and R3 for lower row. Summarized results for this group of stimuli were shown above as Table 2 which for convenience is repeated here :

TABLE 2 (REPEAT)
TWO DOT HORIZONTAL BRAILLE CHARACTERS
(Base : 110 Presentations of each stimulus N=37 subjects )

| | | R1 % | R2 % | R3 % | Total Row % | Other 2 Dot R's % | Total 2 Dot R's % |
|---|---|---|---|---|---|---|---|
| | R1 | 62 | 5 | - | 67 | 5 | 72 |
| Stimulus | R2 | 10 | 45 | 13 | 68 | 7 | 75 |
| | R3 | - | 35 | 26 | 61 | 6 | 67 |

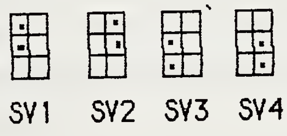
The explanation of vertical or row location error provided in the case of one dot stimuli can be extended here to two dot stimuli as follows. The nature of the stimulus - two dots aligned horizontally to each other - is perceived as a result of two separate judgements as each of the two columnar regions of the braille matrix passes under the finger of the subject. In each judgement a decision is made that there is a dot or no dot above or below a subjective divider of the sensory space. If the subjective midpoint is considered to be variably placed in the vertical plane but centred around a position below the actual point of contact with the mid row position, bottom row stimuli will frequently be close enough to the subjective divider to be responded to as if they were mid row stimuli. Mid row stimuli will be subject to less error since the range of positions occupied by the subjective divider will straddle the mid row stimulus position though skewed in the direction of the bottom row. Top row stimuli will elicit least error due to

their greater mean distance from the subjective positionings of the midpoint and the consequent greater ease with which their location can be recognized as above the mid row position.

Checking data in Table 2 it will be apparent that row results provide a fit to this hypothetical model similar to the one dot results. Thus the top row stimulus is identified correctly as a row code in 67 percent of presentations including 61 percent assigned their correct row position. The mid row stimulus is correctly identified for row in 68 percent of presentations but with a greater spread between rows leaving only 45 percent correctly located in the mid row position. In the case of the bottom row 61 percent of presentations correctly identify a row code but with more than half this number shifted to the mid row position. It is clear that sensing failure is not the reason for the aberrant bottom row data since identification as a row is almost identical with top and middle row stimulus results. As a provisional hypothesis the model is therefore supported to the extent that it provides a consistent fit with a second set of data albeit from the same experimental study.

The remaining two dot characters have dot arrangements - dots aligned vertically or diagonally to each other - which elicit different identification strategies from the subject. Short vertical stimuli will be considered first.

**Short Vertical Stimuli**




The summary tabulation of two dot results (Table 5 above) showed a recognition of short verticals as two dot characters in 66% of presentations and with correct orientation (vertical) in 38% of presentations but with accurate positioning of the two dots in only 12% of cases or 26% of cases if column errors are ignored (the latter statistic is accepted as the better indicator bearing in mind that the only cue available to distinguish character SV1 from SV2 and SV3 from SV4 is a fractional difference in time of presentation).

The tabulation which follows provides a detailed breakdown of these results and illustrates main tendencies in responding to each of the

four short vertical stimuli.

TABLE 6

SHORT VERTICAL BRAILLE CHARACTERS

( Percentage of Presentations of Stimulus Character N=110)

| RESPONSE : | | SHORT VERT. | ROW | SHORT DIAG. | LONG VT/DG | TOTAL 2 DOT | CORRECT RESPONSE |
|---|---|---|---|---|---|---|---|
| SV1 | % | 38 | 18 | 11 | 1 | 68 | 8 |
| SV2 | % | 30 | 23 | 5 | - | 59 | 9 |
| SV3 | % | 43 | 22 | 7 | 1 | 73 | 20 |
| SV4 | % | 39 | 19 | 7 | - | 65 | 12 |
| ALL SV'S | % | 38 | 20 | 8 | - | 66 | 12 (26) |

The results in this table testify to the difficulty experienced by subjects in correctly locating individual dots of a two dot short vertical character. Identification of correct dot number is achieved for 66% of presentations - only marginally below the figure of 70% for row stimuli - but while row stimuli were identified as rows in 65% of cases, for short verticals the vertical orientation (short vertical/long vertical) is identified in only 38% of presentations. In 20% of presentations the vertical alignment of dots in the stimulus is perceived as a horizontal (row) arrangement and in 8% of cases as a short diagonal.

To put these comparisons into context it is necessary to keep in mind the different character of the tasks facing the subject in responding to row and to short vertical stimuli.

In the case of rows the subject has two sequential presentations of a single dot and in each presentation is called on to perform two operations, recognition of a single dot and assignment of the dot to one of three vertical positions. In the latter operation, location of the second dot in the same row as the first (and thus identification of the character as a row), is facilitated by an immediately prior fixation on the first dot in the same vertical position. This in effect locks in a focus of attention on the row

[illegible]

position in which, a fraction of a second later, the back edge dot is presented to the finger surface.

The two dot short vertical character makes a different demand on the subject: here the two dots are presented simultaneously and the subject must make a judgement about number of dots, their alignment - vertical , horizontal or diagonal -, whether the dots are in adjacent rows or separated by a row and whether they are located in the top or bottom segment of the sensory field, all in the same interval of time in which , in the case of a row stimulus , a single dot is presented to receptors in the skin surface.

The results presented above in Table 6 reflect these difficulties. Of particular significance is the pronounced tendency to perceive the two dots as a row and to a lesser degree, a short diagonal. These two types of error response make up a substantial share (28%) of all responses to short vertical presentations and indicate a systematic bias which clearly reflects the operation of factors other than those involved in the sensing of the stimulus. The particular form of the errors also gives support to the conclusion that assigning position to the dots in these instances is not a single act of identification of the dot pattern but rather one of locating the position of dots one by one in sequential fashion.

Thus if character identification were a single act of apprehending a pattern , it is difficult to reconcile the fact that on the one hand the stimulus is a spatial arrangement of dots presented simultaneously to the finger pad surface while the response in the 28 percent of cases referred to above, is a temporal arrangement of dots, one dot succeeding the other. That is the subject responds as if the dots made contact with his finger pad surface at two separate points of time though in fact contact is to all intents and purposes simultaneous.

The same results also provide support for the proposition of a separation of the functions of dot number and dot position identification discussed in earlier sections of the report. Thus if the two functions were part of the same process it would be expected that where two dots are presented simultaneously to the surface of the finger pad a correct identification of dot number would entail awareness that the dots are spatially but not temporally separated. Yet as the above results show , in 28 percent of presentations correct dot number is associated with a response in which the two dots are recorded as temporally separated in the form either of a row or a diagonal. It would seem therefore that the processes are

independent of each other.

Based on this analysis we can now conjecture the steps which the sensory/cognitive system follows in identifying the number and arrangement of dots in a short vertical braille character.

The sequence appears to be as follows. As the first column passes under the finger pad surface, receptors signal two points of contact with protuberances and at the same time provide the input for formation of a short term tactile memory impression.

In the first of these two processes identification of dot number may be at receptor level or it may be in the form of an interpretation of textural quality as suggested by Lederman and Millar. The latter account of the process appears the more plausible since it does not imply simultaneous recognition of spatial or temporal order of the dots and hence is consistent with data indicating separation of functions.

The second process is initiated with formation of a short term tactile memory which appears to persist for no longer than 250 milliseconds (the delay between presentation of the front and back edges of the braille matrix). The memory is scanned in sequential fashion to find the position of the two dots in the column. If scanning of the dots is completed before decay of the memory , both dots of the short vertical will be assigned a position in the same column.

If the speed of scanning is such that only one of the dots is scanned before the memory impression is lost , the second dot is left in a partially indeterminate state, a positionless appendage of the first dot. This dot must actively seek position since the demand characteristics of the experimental situation do not allow a mixed response specifying a position for one dot and not for the other. In the absence of a sensory register of the stimulus other cues to allow positioning of the dot must be sought and these cues must be such as to give the dot both column and row position.

Since on this analysis scanning of the first dot is completed concurrently with decay of the sensory memory and is therefore held in response register , the immediate cues available to determine location of the second dot are the row position of the first dot and a temporal cue resulting from the sequential nature of the scanning operation itself, plus the inferred movement from front column to back column as the tape passes under the subject's finger. In the absence of cues from the sensory memory either or

both of these temporal cues will act to impose a serial relationship between the two dots. This ensures placement of the second dot in the back column, resulting in the short vertical stimulus being perceived either as a row character or as a diagonal character.

In assigning row position to the second dot the only cue is row position of the first dot and the dominant influence of this cue can be judged from the fact that a majority of non-vertical responses (20% out of a total of 28% presentations) record the two dots in a row formation. In only a minority of responses (8% of presentations) is the second dot placed in a diagonal orientation to the first dot. There seems little doubt therefore that the main cue determining the row position of the second dot is the row positioning of the single dot scanned before decay of the front column sensory register.

The following table shows that the types of error on which the above analysis is based is consistent over all four short vertical characters.

TABLE 7

SHORT VERTICAL BRAILLE CHARACTERS : ROW AND VERTICAL RESPONSES

| | RESPONSE CHARACTER | | | | | | |
|---|---|---|---|---|---|---|---|
| | SV1/SV2 | SV3/SV4 | R1 | R2 | R3 | TOTAL ROW | TOTAL ROW/DIAG. |
| | (Base : 110 presentations of each stimulus N= 37 subjects) | | | | | | |
| | % | % | % | % | % | % | % |
| SV1 | 21 | 17 | 5 | 12 | 2 | 19 | 30 |
| SV2 | 17 | 13 | 12 | 7 | 5 | 24 | 28 |
| SV3 | 11 | 32 | - | 14 | 8 | 22 | 30 |
| SV4 | 6 | 33 | 3 | 11 | 5 | 19 | 26 |
| ALL SV'S | 14 | 24 | 5 | 11 | 5 | 20 | 28 |

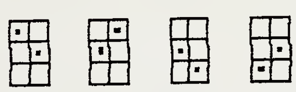
Apart from confirming the consistency of error for all four short verticals, two other features of the above results are worthy of note. One is the higher proportion of lower cell characters (SV3 and SV4) correctly identified as short verticals and given their correct lower cell positioning. The other is the tendency in the case of row responses for the two dots to be assigned a mid row rather than a top or lower row position; only character SV2 runs counter to this tendency.

Both of these results suggest that the first dot scanned is more likely to be the dot located in the mid row position rather than in either of the other two positions. The better identification of lower cell characters (SV3 and SV4) in their correct (lower) cell positions also indicates that it might be easier for subjects to scan down rather than up from the first dot.

Certain results in this tabulation have an indirect bearing on the major hypotheses of the study. Prima facie, the better identification of lower cell short verticals judged on correct positioning in upper/lower regions of the matrix (32 percent and 33 percent for SV3 and SV4 against 21 percent and 17 percent for SV1 and SV2 respectively) suggests better receptor sensitivity away from rather than near the tip of the finger pad. This is contrary to indications dot positioning results have provided up to this point favouring the upper or distal regions of the finger pad surface. The present results can be considered therefore as simply another testimony to the strength of cognitive factors ( here apparently dot scanning order ) in distorting the sensory input and their often dominant influence in determining the final response pattern.

Data from the analysis of short vertical stimuli have been discussed in some detail because of features of the results allowing certain inferences about the manner in which the tactile system senses and identifies punctate stimuli. The following section which discusses responses to short diagonal stimuli illustrates additional features of the identification process.

**Short Diagonal Braille Characters**



SD1 SD2 SD3 SD4

The manner in which short diagonal stimuli and row stimuli make contact with the finger pad is similar in that one dot passes under the subject's finger followed a fraction of a second later by a second dot. The one significant difference is of course that the second dot of the row stimulus is in horizontal orientation to the first dot , that is it is in the same row, whereas the second dot of the short diagonal is one row up or one row down from the row position of the first dot.

This difference , as results in Table 5 above demonstrated , has

a marked effect on the number of correct identifications of dot number and position. A comparison of the two sets of results shows, for example, that against 70 percent correct identification of dot number in the case of row stimuli, short diagonal presentations elicited a 50 percent correct dot number response. Again, correct identification of orientation of the two dots is 65 percent in the case of rows but only 20 percent for short diagonals while a correct complete identification of the character is achieved for 44 percent of presentations for rows and 12 percent for the short diagonal stimuli.

Short diagonal characters , on these results , clearly present a greater degree of difficulty for the subject than either row characters or short verticals. The difficulty also takes a different form as the following tabulation illustrates.

TABLE 8
SHORT DIAGONAL BRAILLE CHARACTERS

RESPONSE CHARACTER

( Base : 110 presentations of each stimulus N= 37 subjects )

| | | ROW | SHORT VERT | SHORT DIAG | 2 DOT TOTAL | 3 DOT TOTAL |
|---|---|---|---|---|---|---|
| SD1 | % | 25 | 5 | 14 | 46 | 49 |
| SD2 | % | 11 | 19 | 23 | 54 | 38 |
| SD3 | % | 16 | 14 | 17 | 48 | 45 |
| SD4 | % | 17 | 9 | 23 | 52 | 42 |
| All SD's | % | 17 | 12 | 19 | 50 | 44 |

(Not included in the table are a total 2 percent long vertical and long diagonal and total 6 percent four dot and one dot responses)

A striking feature of the results is the high percentage of three dot responses - 44% of all responses (against 13% for row stimuli). This result is due in a majority of instances (72% of all three dot responses) to a tendency to convert the diagonal into a short angular character formed by the addition of a third dot in the same row as the front edge dot - for example a diagonal with dots in positions 1 and 4 of the braille matrix is

converted into an angular character by the addition of a third dot in position 2.

On first examination these results suggest a tactile processing system well equipped to respond to lines vertical or horizontal to the direction of movement of the finger surface or to angular forms consisting of horizontal and vertical dot alignments, but not equally well equipped to recognize diagonal arrangements of the dots. While superficially attractive, an hypothesis in such general terms will be seen to have limited explanatory value, and so far as the problem of angular responses is concerned provides no answers to key questions. It offers no rationale, for example, to explain the existence of the third , illusory , dot nor does it explain why in a substantial number ( 19 percent ) of responses the number and spatial relationship of dots in the diagonal character are correctly identified.

While not dismissing totally the notion of a structural bias at cortical level it is apparent that perception of a short diagonal as an angular character involves other processes. An examination of the form of angular responses in itself does not reveal much about the character of these processes but there are certain inferences which can be drawn from examination of responses in which the short diagonal is reported as a row character.

It should be noted firstly that, counted over all presentations of the four short diagonal stimuli, the row response is recorded in an average 17 percent of instances, a result only marginally less than the 19 percent in which the short diagonal form of the character is correctly identified. The row type error is therefore a substantial component of total responses.

An explanation of the row response which has some prima facie plausibility is that there is imperfect sensing of the back column dot position. This however is not a fully satisfactory explanation bearing in mind that a row focus is already established in positioning the front column dot and that the diagonal position of the back column dot requires no more than detection of a shift up or down from this point of focus.

To arrive at a more satisfactory explanation it is instructive to refer back to the analysis of one dot characters. This analysis showed (see Table 4 above) that for characters consisting of a single dot located in the front edge of the braille matrix (dot positions 1,3 and 5) 82 percent of responses correctly identified dot number and 63 percent of responses

correctly positioned the dot in the front edge column. However , in an additional 12 percent of presentations (not shown in Table 4) the response took the form of a two dot row character. That is , even when the stimulus character is a single , front edge dot with an empty back edge column, there is a quite strong tendency to add an illusory second dot in the empty column , positioned in the same row as the stimulus dot of the front column. Incidence of this effect is substantial enough to rule out a likelihood of it being due to an oddity of sampling of the population in question. The low incidence of responses in which a second dot is added in other positions in the back column ( less than 2 percent for diagonal placements of the second dot) further supports the conclusion that a systematic process is involved.

The importance of this result in explaining the row response to short diagonal stimuli will be apparent. In both cases a single dot in the front column is correctly identified but followed in the back column in a substantial proportion of responses by a "false" dot in the same row position as the first dot. In the case of the single dot stimulus the back column is empty and the added dot is illusory; with the short diagonal the back column contains a dot which is identified for number but shifted vertically to an empty cell position to complete the row response. The analogy with one dot stimulus results permits the conclusion that of the 17 percent of short diagonal presentations eliciting a row response , an approximate 12 percent can be explained as due to the illusory dot effect - the illusory dot in these instances being substituted for the real dot , identified for number but not position.

If we revert now to the problem of the angular response, the situation as described above is that in 32 percent of all presentations of the short diagonal stimulus the two dots are correctly positioned in diagonal alignment but with an added dot completing a row with the front column dot thus forming with the two dots of the stimulus a short (right) angle response.

Overall in nearly half (49 percent) of the total number of presentations of short diagonal stimuli the front edge dot of the diagonal elicits a dot in the back edge in the same row as the first dot, in the one instance converting the diagonal into a row character (17 percent of responses) and in the other case into a short angle character (32 percent of reponses).

The phenomenon of the added dot , on the available data, is not satisfactorily explained in terms of sensory error and the following discussion will therefore review a likely series of cognitive operations

leading to the emergence of the dot in subjects' responses. This is substantially the same sequence of processing events identified in earlier analyses in this report

Firstly, as the front column of the matrix passes under the subject's finger an impression of dot number is signalled to the brain. In a separate and independent operation, a series of briefly existing sensory memories is formed registering a train of skin deformations as the tape moves across the finger surface and dot or dots in the column make contact with different receptor regions in the finger pad. A similar process of short term memory formation and decay will accompany the passage of the back column under the finger. The distance separating the two columns ( 2.5 mm from dot centre to dot centre) however is such that there will be a period of overlap during which the two columns will both be signalling and maintaining sensory registers in the brain simultaneously.

For the duration of time in which a brief memory impression of both front and back edge is available to the subject what will register as the content of the back edge will depend on which memory impression - front or back edge - is the focus of attention at the time. Confusion will result when attention is directed at the contents of the front column while the back column register is also available.

Thus in the case of the single dot character with dot located in a front edge position, if the memory impression of this dot is still in focus when a sensory register of the ( empty ) back column is also available to the brain, the dot is likely to be 'read' as occupying a position in this column as well as in the front column. This happens presumably when memory register of the front edge dot persists without decay during shifts of attention first from the front edge column to the temporal event signalling movement to the back edge column and finally to a focus on this latter column. In this sequence the dot registered in the front edge column is carried over into the attentional area of the back edge column and is given a location in this column as well as in the front column.

An analogous series of events in the case of short diagonal characters will lead to a 'reading' of the diagonal in the one instance as a row, in the other as an angular character. The difference in outcomes appears to be related to the speed and effectiveness with which sensory registers are scanned - where the diagonal is recorded as an angle character scanning of the (real) dot in the back column is completed before the memory impression decays; where a row response is recorded, decay of the

back column memory occurs before the contents are scanned to add a second ( back column ) dot to the illusory dot repeated from the front edge column.

The high incidence of the illusory dot in the case of angular responses may reflect in part a central process favouring completion of the angle form but a more likely explanation is that the additional information load of a 'real' dot in the back column has the effect of facilitating dot repetition from the front column. That is , the attentional resource which would otherwise be available to block dot repetition is diverted to the task of position identification of the back column dot. The sequence then can be conjectured as follows :

- front edge column makes contact with the skin surface and sets up first in a train of sensory registers of front edge dot
- front edge dot identified for number and position
- subsequent registers of front edge dot are signalled to the brain along with first in train of registers of the back edge dot
- the two trains of sensory registers occurring together signals movement from front to back edge column
- recognizing temporal shift should block further intrusion of front edge registers into identification process but attention shift to analyse contents of back column allows them to persist and to record a dot in the back column
- finally back column dot identified for number and position.

One other type of error ensuing from column confusion is recorded in Table 8 results. This is the response in which the two dots of the short diagonal stimulus are reported as a short vertical character. The error is recorded in 12 percent of all presentation of the four short diagonal stimuli.

In these responses , subjects, while recognizing spatial separation of the two dots have not detected their temporal separation. In terms of the above analysis this can be interpreted to indicate a failure to note the fractional difference in time of onset of the train of front column and back column sensory registers but a strong focus on the two registers

during the span of time in which they are signalling to the brain simultaneously.

A significant demonstration of the way in which attention fluctuates between spatial and temporal features of the stimulus is apparent in the complementary relationship of row and short vertical responses to the short diagonal stimulus. That is a short diagonal character eliciting a high response as a row character has a relatively low incidence of response as a short vertical. Conversely a high response as short vertical is coupled with lower response as a row character. There is an obvious trade off between the two responses.

Thus ( Table 8 above ) character SD1 is responded to as row in 25 percent of cases and as short vertical in 5 percent of cases; SD2 11 percent and 19 percent; SD3 16 percent and 14 percent; SD4 17 percent and 9 percent. That is, for characters SD1, SD2 and SD3 total identification as either row or short vertical adds to 30 percent of responses though individual percentage results of rows versus short verticals show a marked variability from character to character. For character SD4 the total is 26 percent, only marginally less than the 30 percent result for the other three codes.

The remarkable consistency of totals combining row and short vertical responses supports findings from analysis of individual response categories. It demonstrates, for example, the limited attentional resource available to the subject in scanning a sensory register. Thus, where there is undue persistence of focus on the spatial (vertical) position of the two dots, there is a substantially reduced likelihood of detection of temporal separation; where movement of the braille cell from front to back column is the main focus, vertical difference tends to be missed.

Results for individual short diagonal characters reflect differing emphasis in respect of each of these two attentional foci. The emphasis elicited by a character is presumably determined by both the vertical position of the first dot relative to the second dot presented to the finger pad and also the row position of the first dot. The operation of these two positional factors is however complex. Thus top half characters (SD1 and SD2) illustrate a pattern in which a higher row position of the first dot (SD1) elicits a stronger row response while a higher position for the second dot (SD2) produces a result in which the row response is weaker than the short vertical response.

This pattern is however not found in the bottom half characters (SD3 and SD4). Other results in Table 8 illustrate a similar complex relationship between factors. At this stage the exact nature of the mechanisms involved is not clear though the main premise of the argument that a dominant focus on one aspect of the stimulus reduces the likelihood of accurate identification of another feature, is clearly demonstrated.

To complete this analysis some reference should be made to responses in which the short diagonal stimulus is correctly identified. To arrive at a correct response a sequence of judgements must be made. The front edge dot must be correctly identified for number and position then, following onset of the train of sensory registers of the back edge dot, column separation must be signalled to the brain and at the same time an attentional block placed on front edge registers to avoid the repeated dot effect ; finally the back edge dot must be correctly identified for number and position and this information related to front edge dot number and position to form the response character.

When the incidence and range of error in response to the short diagonal stimulus is considered it is obvious that achieving a correct response requires a sustained and concentrated attentional effort directed at the sensory input data. Most errors of identification appear to reflect either failure to sustain a high level of attention to the input during passage of the stimulus across the finger surface or, more likely, a consistently low level of attentional effort resulting in slow speeds of processing the sensory data.

Based on the analysis of short diagonal responses the following provisional conclusions of a general nature can be offered :

- the speed with which tactile data is scanned is quite slow and is significantly affected by momentary and apparently quite small fluctuations in attention to the stimulus

- slow scanning speed is due to the very limited capacity of the tactile attentional resource reflected among other features in the fact that a slight change in the arrangement of dots in a stimulus such as a shift of a dot up or down one row position (short diagonal versus row) can

produce radical disturbance of the identification process.

- due to slow scanning speed multi-row dot stimuli tend to overload the tactile sensory/perceptual system resulting in a high rate of error in identifying dot positions.

- a linear code using dots or other device might offer a more efficient means of information transfer than the present multi-row braille system.

- dot position and dot number appear to be signalled to the brain by separate neural channels but complementarity of spatial and temporal positioning errors indicates that spatial and temporal features of a stimulus are signalled by a single channel.

In the next section of the report responses to long vertical and long diagonal characters will be briefly discussed. The main value of these results is demonstration of a tendency towards closure of the gap between dots separated by an empty middle row position.

## Long Vertical and Long Diagonal Stimuli

LV1 LV2 LD1 LD2

TABLE 9

LONG VERTICAL AND LONG DIAGONAL BRAILLE CHARACTERS
(Base : 110 presentations of each stimulus N= 37 subjects)

| | 2 Dot Responses | | | | | 3 Dot Responses | | Other R's |
|---|---|---|---|---|---|---|---|---|
| | LV | LD | Row | SV | SD | All Rows | Other | |
| | % | % | % | % | % | % | % | % |
| LV1 | 12 | 5 | 4 | 18 | 3 | 34 | 16 | 7 |
| LV2 | 17 | 6 | 3 | 21 | 9 | 20 | 21 | 2 |
| LD1 | 3 | 16 | - | 5 | 8 | 31 | 30 | 7 |
| LD2 | 10 | 17 | 1 | 5 | 5 | 20 | 25 | 16 |

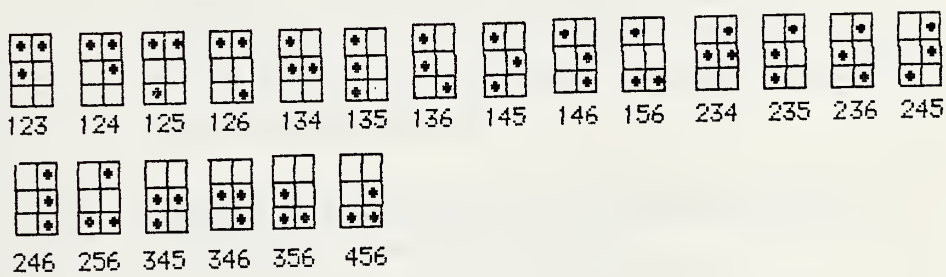
The results in this tabulation illustrate a number of important points. Most noteworthy is the tendency to add a third dot to the two dots of the stimulus , most frequently to a mid row position. This occurs in thirty percent or more of responses in the case of LV1 and LD1 and 20 per cent in responses to both LV2 and LD2. Two processes seem to be involved. The primary process is a closure of the gap separating the dots in the top and bottom rows , and is reflected in the high incidence of responses with a dot in all three rows. The added dot in these instances gives a semblance of pattern to the braille character and presumably makes it easier for the brain to record and transfer to the response register. The link between this process and the Gestalt principle of closure will be recognized.

The second of the two processes is identified by the positioning of the added third dot in short angular formation with the other two dots. The illusory third dot in these cases can be assumed to owe its existence to the same process which supplies a third dot to short diagonal characters and to front edge single dot characters ( see discussion of short diagonal characters ).

A further point of interest is the tendency to collapse the row distance between dots to form short verticals and short diagonals. This may be due to failure to sense the spatial separation of the two dots or may be another form of the reaction to discontinuity. Not surprisingly this type of error occurs more frequently in presentations of long vertical characters.

So far as the main hypotheses under test are concerned, the results for this set of characters provide no evidence of a sensory deficit on regions of the finger pad making contact with top or bottom rows of the braille matrix.

## 10.23 Three Dot Braille Characters




Three dot braille characters because of the more complex arrangement of dots do not permit the same degree of detailed analysis as two dot characters. Treated in summary form however the results do throw further light on features of the perceptual process and also serve to support some of the hypotheses proposed above.

The following Table 10 is a summary from a more complete tabulation of results included as Appendix. 8. It shows mean values on a range of response categories for eighteen of the twenty three-dot codes. The codes , and corresponding means , were analysed in two groups, the first group comprising nine codes in which the single dot occupies a row position in the front column of the matrix , the second group codes in which the single dot is located in the back column. The two codes in which the three dots are located in a single column are omitted from this part of the analysis.

The five response columns provide the following information:

<u>Column 1</u> : Percentage of responses in which <u>dot</u>

number is correctly recorded.

Column 2 : Percentage of responses reporting correct dot number in both front and back edges.

Column 3 : Percentage of responses correctly reporting three dots for the code and correct position of dot or dots in front edge column of the braille matrix.

Column 4 : Percentage of responses correctly reporting three dots for the code and correct position of dot or dots in back edge column of the braille matrix.

Column 5 : Percentage of responses correctly reporting both dot number and dot position of the three dots of the code (that is correctly identifying the braille character).

Column 6 : Percentage of responses identifying stimulus as a two dot character.

Column 7 : Percentage of responses identifying stimulus as a four or five dot character.

(total of columns 1, 6 and 7 gives the percentage of responses identifying the stimulus character as a 2,3,4 or 5 dot character).

TABLE 10

THREE DOT BRAILLE CHARACTERS

(Base 110 presentations of each character N=37 subjects)

CODES WITH ONE DOT IN FRONT EDGE/ TWO DOTS IN BACK EDGE

| | 1 | 2 | 3 | 4 | 5 | *6* | *7* |
|---|---|---|---|---|---|---|---|
| CODE | DOT NO. CORRECT TOTAL % | DOT NO. CORRECT BOTH COLS. % | DOT POSNS. CORRECT FRONT EDGE % | DOT POSNS. CORRECT BACK EDGE % | CODE CORRECTLY IDENTIFIED % | *TWO DOT RESPONSE %* | *4 AND 5 DOT RESPONSE %* |
| COL. MEANS | 54 | 36 | 22 | 20 | 13 | *11* | *34* |

CODES WITH TWO DOTS IN FRONT EDGE/ ONE DOT BACK EDGE

| | 1 | 2 | 3 | 4 | 5 | *6* | *7* |
|---|---|---|---|---|---|---|---|
| COL. MEANS | 51 | 21 | 12 | 11 | 7 | *16* | *30* |

Note : For convenience in the following discussion the two groups of codes in the tabulation will be designated the one dot group and the two dot group, the reference being to the number of dots in the front edge column of individual codes of the group

The first point to note is that the earlier finding of functional independence of dot number and dot position identification is supported. Thus , while there is substantial variability in the performance of the two groups in respect of dot positioning ( Columns 2 , 3 , 4 and 5 ) in the case of dot number identification mean correct responses for the two groups - 54% for codes with the single dot in the matrix front edge and 51% for codes with two dots in the front edge - are almost identical indicating approximately equivalent performance on this criterion.

An analysis of variance to check the possibility of a statistical artifact producing the close equivalence of dot number results for the two groups of codes shows that neither sex of the subject nor sequence of codes is a significant contributing factor ( see Statistical Appendix 2 ).

Results for dot positioning as already noted show a marked disparity. Thus correct responses for the two dot group of codes have a mean

value only slightly better than half the rate achieved for the <u>one dot group</u> - 12% and 11% respectively for front and back edge respectively in the first group against 22% and 20% in the second group ( mean values in columns 3 and 4 ).

The comparison indicates that while correct positioning of the dots is highly sensitive to an increase in the number of dots in front edge positions, a correct judgement of dot number is not. If the two operations were part of the same process it would be expected that a difference between the two groups on one criterion (positioning dots in their correct matrix column) would be matched with a similar degree of difference on a second criterion ( identifying the correct number of dots). Since this is not the case it can be concluded with some degree of confidence that separate brain processes mediate the operations of judging dot number and assigning dot position.

A further significant feature of the results is illustrated in the discrepancies between correct assignment of dot number by column (Column 2 percentages in the above tabulation) and judgement of dot number in total for the character (Column 1 results). As noted above in the analysis of short diagonal responses, the width of a braille character measured from dot centre to dot centre in the same row is 2.5 millimetres but the surface of the finger pad making contact with the character is approximately in the range 12 to 15 millimetres. This means that dots in the back edge column make contact with the pad surface while dots in the front or leading edge column are still moving across that surface. In fact dots in both columns will be in contact with receptor cells over a distance of eight or more millimetres of the finger surface.

The brain is therefore receiving two trains of impulses simultaneously and is presented with the task of distinguishing the two sets of messages based on recognition of a series of quite small interdot differences as dots in the two columns travel together across the finger surface. If the focus of attention is maintained on the front edge dots until these are fully identified and only then shifts to the back edge dots there should be no confusion. If, however, attention shifts between the two sets of sensory messages before the front edge dots are identified there is likely to be confusion as to which dots are located in which column.

A measure of this confusion is the deficit in correct dot number responses <u>by column</u> in the one and two dot groups. Thus subtracting the mean value for correct dot number by braille matrix column ( Column 2 in

Table 10 ) from the mean correct dot number identification in total ( Column1 in Table 10 ) the 30 percent deficit for the two dot group of codes will be seen to be almost twice the deficit of 18 percent for the one dot group.

A conclusion that can be drawn from these results is that the number of dots in the front edge of the matrix influences the time taken to scan this column and that scanning time is in a linear relationship with the rate of error in assigning dots to their correct column. In other words the less time it takes to scan for dot number the less likelihood there is of a premature shift of focus when the back edge dot or dots begin their passage across the finger pad surface and the less likelihood of a front edge dot being attributed to the back column. At a more general level the results also confirm that identifying dot number is subject to processing time constraints of possibly the same order as identifying dot position. This was not apparent in the earlier analyses of one and two dot characters.

## Missed Dots and Added Dots

The analysis so far has dealt only with responses reporting correct dot number for the the three dot stimulus character. Responses in which dot number is reported incorrectly also throw light on the processes by which dot number is identified. Columns 6 and 7 of Table 10 above record the incidence of the two categories of incorrect dot number response - the missed dot and the added dot response ( one dot and six dot responses are not shown because of negligibly small incidence of occurrence ).

Consulting the full tabulation in Appendix 8 , it will be noted that missed dot responses are recorded mainly for codes in which two dots make a row and with the third dot form a short angle, e.g. character 124 ; the missed dot in these responses is most frequently the third dot diagonal to the row, suggesting that crowding of dots in short angle characters leads to confusion either at sensory level or in higher level scanning of dot number. The analysis above dealing with errors involving positioning of dots in the wrong column indicated a significant time constraint on scanning dot number and the constraint was reflected in this type of error. At the same time missed dot errors are substantially fewer where dots are less crowded, indicating that errors may be at least partly due to a failure of sensory receptors to distinguish vertically adjacent dots.

In the case of added dots the majority of responses add a fourth dot either to complete a row, for example a dot in position 3 added to stimulus character 124, or to fill an empty space in a vertical, for example a dot in position 4 added to stimulus character 126. In both examples the added dot results in a simplification of the response character and appears due to an overload on the attentional capacity and a loss of complete information regarding dot number.

To complete the discussion on missed and added dots it is necessary at this point to interpose a comment on the two three dot vertical braille characters.

## Three Dot Vertical Characters

The two braille characters in which all three dots are located in the one column are defined by the dot positions 135 and 246. As the only cue to distinguish between these two codes in the experiment is a fraction of a second difference in time of presentation, for analysis purposes responses135 and 246 will be treated as equivalent , and in the case of missed dot responses the pairs 13 and 24 and 35 and 46 will also be treated as identical.

Adding responses in this way both three dot vertical codes are found to have a higher level of correct identification of the complete code than other three dot characters : 30 percent for Code 135 , 25 percent for Code 246. Both codes also record a much higher level of missed dots (31 percent and 41 percent) but a lower level of added dots (14 percent for both codes) than all other characters. Missed dot responses in a large majority of cases (73 percent for Code 135, 84 percent for Code 246) involve a loss of the dot in top or bottom row positions (positions 1 or 2 or 5 or 6). Because of the large number of missed dot responses, correct dot number identification ( 53 percent for 135, 45 percent for 246) is a little below the mean result for other three dot characters.

Putting these pieces of information together it is evident that while three dots in the same column places a considerable load on the processing system reflected in the high level of missed dot responses, the completely filled matrix column when fully scanned immediately fixes all dot positions in the column and makes complete identification of the code a quicker and hence easier operation compared with three dot codes in which

the dots are distributed between columns. The last point is illustrated by the fact that correct identification is nearly three times that for other three dot characters (30 percent for Code 135, 25 percent for 246 against a mean result of 10 percent for other three dot codes).

A final result worth noting is the position of missed dots. As reported above the missed dot in the big majority of instances is in the top or bottom position of the column. This suggests that the dot enumerative process either 'chunks' the braille matrix into upper or lower regions or scans dots sequentially from top to bottom or bottom to top. In either case the tactile memory impression in instances of missed dots obviously decays before inspection for dot number is completed.

The discussion of three dot vertical characters has dealt with column positioning as well as dot number identification. This was done as a matter of convenience because of special features of the stimuli. The discussion will now be directed to analysis of positioning of dots by columns for three dot characters included in Table 10 above.

## Positioning of Dots within Columns

In this section the discussion deals with the statistics presented in columns 3, 4 and 5 in Table 10 above and is concerned with factors determining correct row placement within a column.

A first inspection of results shows that establishing the correct number of dots in each of the two columns of the braille cell , while a necessary precondition for placement of dots in correct row positions , does not in itself lead invariably to a correct response. In fact, calculated over all codes, a maximum 60 percent of responses which correctly reported column dot numbers also correctly reported row positions of dots in each braille column (Columns 3 and Column 4 total responses as percentages of total responses Column 2). Thus in the <u>one dot group</u> of codes, of all responses correctly allocating a single dot to the front edge matrix column and two dots to the back edge, only 61 percent also correctly reported the row position of the front edge dot and 56 percent the positions of the two dots in the back edge.

Corresponding results for the <u>two dot group</u> were 57 percent correct row positions for the two dots in the front edge and 50 percent for the single dot in the back edge.

These results are better than the 33 percent result expected by chance but not all that much better. The figures of 50 to 60 percent correct positioning responses still leave 40 to 50 percent of instances in which a dot or dots are incorrectly positioned even though allocated to the correct column. The result adds weight to the conclusion that identifying the correct dot number in a column is not directly related to the process by which vertical position in the column is established.

It will be noted that while the group of codes with one dot in the front column has almost double the number of correct column dot number responses compared to codes with two dots in the leading edge (36 percent versus 21 percent), this advantage does not hold in a comparison of front and back edge positionings within each group of codes. Thus in both one dot and two dot groups , the column with two dots has almost the same number of correct vertical positionings as the column with one dot - 20 percent versus 22 percent for the one dot group, 12 percent versus 11 percent for the two dot group.

The apparent conflict with the finding that two dots take longer to scan than one dot can be attributed to what may be termed a 'front edge cueing factor'. This is quite simply a tendency for front edge dot or dots, once assigned vertical positions, to act as reference points for vertical positioning of back edge dots. A first effect resulting from operation of the factor is the level of correct braille character identifications (Column 5) which is substantially higher than would be predicted from results of correct dot positionings in individual columns. A second effect is elimination of the normal advantage a one dot positioning has over a two dot positioning noted for example in front edge dot positionings of the one dot group versus the two dot group of codes.

The 'front edge cueing factor' while performing an important role aiding correct character identification, is subject to distortion by a number of other factors. For example, separated dots as in the back edge of character 236 ( see Appendix 8 ) introduce a biasing effect mostly reflected in the addition of a fourth dot to the character (not always in the back edge column) and rendering the cueing factor ineffective. A reverse process is noted in the case of code 145 where the separated dots are in the front edge and a total failure by subjects to correctly identify their positions means there is no cueing provided for the back edge with the result that the single dot located there is correctly positioned in only 4 percent of presentations. The effects of column confusion , due apparently to fluctuating attention

since dots in both columns traverse the finger surface simultaneously , are seen in responses to a number of codes, for example 356 and 456.

The complex of factors impingeing on the identification process mean that those factors facilitating accurate identification are frequently blocked and functionally inactive. In this respect fast scanning of component dots of a braille character is clearly of critical importance if intrusion of distorting factors is to be avoided.

It is now possible to see that an information overload can affect identification in a number of ways. Firstly if the sensory register decays before the contents are fully scanned, there is total loss of a dot or dots. Secondly, in cases of uncertainty about dot positions, for example as a result of confusion when two column sensory registers are present in the sensory field simultaneously , cognitive factors are likely to add to or distort the sensory data. Such tendencies appear to represent inherent cognitive dispositions, for example to avoid discontinuity by filling an empty position between dots or to achieve symmetry by adding a dot to complete a square.

Identifying a braille character therefore, rather than being a passive operation of sensing and transmitting information to the brain, appears to be in varying degrees a dynamic process in which the brain adds to and changes what reaches it in the form of sensed data. The difficulty of identification of braille characters with three or more dots reported in earlier research studies and confirmed in the present study can with some certainty be attributed to these factors quite as much as to simple failure to sense dot number or position.

## 11. CONCLUSIONS

Criteria decided on initially for test of the principal hypotheses of the study were : (1) identification of dot number (2) identification of dot position in the braille matrix. Using these criteria a test of relative acuity in different regions of the finger pad skin surface would then consist in comparison of error frequencies based on responses to stimuli consisting of a dot or dots occupying different rows of the braille matrix.

Of the two test criteria it was anticipated that dot number would be the more sensitive measure since it was less likely to be affected by extraneous factors stemming from judgements about spatial referents of the braille matrix. Data from the research supported this conjecture and the main test of the hypotheses was restricted to dot number responses , dot positioning results serving the supplementary purpose of defining some of the non-sensory features of the braille character identification process.

Based on dot number responses , an analysis of one dot and two dot row responses generally confirmed the null hypothesis in respect of proximal/distal regions of the finger pad corresponding to row positions of the braille cell. Both sets of stimuli elicited dot number responses for row positions which exhibited a marked equivalence in purely numerical terms and taken together the two sets of results confirmed that if regional sensitivity differences existed they were probably of very limited significance so far as the identification of braille characters is concerned.

One dot stimuli permitted a test of accuracy of response to dots in front edge versus back edge columns of the matrix. While not a test of relative acuity , results showed no serious deficit of correct response for either column , indicating that on the criterion of correct dot number , the slight difference in time of presentation of dots in the two columns has no noticeable effect on responses.

Short vertical and short diagonal results , comparing correct dot number responses for upper and lower characters ( a mid row dot with the second dot in top or bottom row position) , again showed no tendencies

reflecting a systematic weakness in top or bottom regions of the braille cell.

Three dot codes because of more complex dot arrangements, were not so easily applied to a test of regional sensitivities but a comparison of results for codes with two dots in the top row versus two dots in the bottom row with a common mid row dot, showed minimal differences in correct dot number identification.

An assessment based on the different sets of results allowed a conclusion that under conditions of the experiment no significant sensitivity differences existed in regions of the skin surface corresponding to positions in the braille matrix and all null hypotheses were therefore confirmed.

Analysis of dot positioning results for one and two dot characters revealed a significant variability in correct response rates for different row codes. This variability and the absence of significant variability in the case of dot number responses led to the inference that dot positioning was affected by non-sensory factors and on this indication analysis was directed at investigation of the source and operation of these factors.

Since dot number identification showed a consistent regularity and dot positioning a marked irregularity in paired responses in all analyses, a first conclusion was that the two functions are served by different neural pathways and are integrated only at cortical level. Based on this assumption it was thought likely that judgement of dot number may not be an enumerative process but might be based on textural impressions of the type suggested by Millar and Lederman. Evidence that correct identification of dot number is affected by an increase in the number of dots in a braille code, however, indicated that this was unlikely to be the case and the evidence suggested that the process may in fact be enumerative. In either case it seems likely that input is mediated by the Pacinian receptor system which registers the presence of protuberances on a surface but not location and is apparently also responsive to vibratory stimulation by which textural differences are judged.

Identifying dot positions , on indications from error data , is an analytical process operating on short term memory registers and consisting of a sequential scanning of contents. Most errors appear to be due to failure to complete scanning before decay of the memory register. Such failure appears to be an effect of information overload or of a lack of adequate spatial referents which would enable a quick allocation of dots to regions and positions in the braille cell.

Analysis of three dot characters indicates that there is something like a one to one relationship between the number of dots in a column and the time taken to scan them for position. Where cues are provided by correct positioning of a dot or dots in the front edge of the matrix, however, errors in positioning of two dots in the back edge column are no greater than for a single dot.

Temporal separation of dots located in different columns appears to be achieved by inspection of separate short term memory registers for each column. Spatial and temporal features of the braille character accordingly form parts of the same scanning operation and have a complementary relationship. This relationship is demonstrated in error responses to short diagonal characters. For each of these four characters the addition of row and short vertical responses is a constant percentage of total responses although individual row and short vertical response rates are variable from character to character. This result indicates that temporal separation of dots is scanned in the same process as spatial separation with shifts in attentional focus from one feature to the other. It also confirms that scanning of punctate stimuli is slow relative to the rate of decay of short term memory impressions with the result that a dominant focus on one feature - spatial or temporal - increases the probability of loss of information about the other feature. The scanning process is best understood by examination of the physical parameters within which it operates.

Since the width of the braille matrix is 2 mm and the average width of the distal surface of the index finger pad is 12 mm to 15 mm , dots in both columns of the braille matrix traverse the finger surface simultaneously over a distance of 10 to 12 mm. Accordingly , two trains of impulses are transmitted simultaneously to the brain and , in terms of the

hypothesis , two sets of short term memory impressions are formed over the duration of the traverse. The brain must scan both sets of impressions and distinguish them on the basis of time of onset in order to provide accurate column identification. If the scanning takes the form of alternate attentional focus or if the front edge memory impressions are imperfectly scanned before a switch of attention to the back edge impressions , the opportunity for error is greatly enhanced , leading to a confusion of columns as , for example , in misidentification of a short vertical as a row character.

The overlapping memory registers of front and back edge columns also provides an explanation of the phenomenon of the illusory dot , noted in responses to the the short diagonal and also the single dot character with dot in the upper row of the back column. In the case of the single dot character ,12 percent of responses added a dot in the back column resulting in a row response. A similar occurrence in the case of the short diagonal added a dot in an empty position in the back edge column to form a three dot angle response. In both cases the effect appears to be due to persistence of the image of the (real) front edge dot during a switch of attention to the temporal event ( movement of the tape under the finger signalling movement to the back column position) followed by a refocus to the front edge register which is now incorrectly assigned to the back edge column.

Much of the analysis of dot positioning processes is speculative and obviously requires validation under a different set of experimental conditions. Nevertheless the main proposition that identification is an analytic process operating on short term memory registers is supported consistently in all sets of response data and an alternative interpretation with a similar fit to the experimental data is at this point difficult to formulate. Similarly the evidence for the proposition of separate neural pathways for transmission of dot number and dot position inputs is a consistent feature of results for all sets of stimuli included in the analysis. On the ground of consistency there is reason to believe therefore that the identification model proposed in the discussions may be a reasonably accurate account of the processes by which punctate stimuli of braille dimensions act on the sensory/ cognitive systems and elicit a response appropriate to the experimental or other braille reading situation.

The implications of the research for the reallocation of braille codes as suggested in the paper by Sutcliffe are favourable in that there appears to be little variability of sensitivity across the area of the finger pad surface used in reading braille. If codes were to be reallocated , therefore , differential tactile acuity is not likely to act as a confounding variable.

Other implications of the findings however are not encouraging for the present braille reading system. A major and inherent problem appears to be the use of multi-row codes. Subjects experienced little difficulty identifying a dot or dots in a single row but major information overload is encountered when dots occupy different rows and a shift of focus is required up or down from the row position of the first dot scanned. A linear code might present its own difficulties but on the evidence of the present research it would eliminate some of the problems in the present system and might just conceivably help to improve reading speed for the visually handicapped to a level above that achieved with the braille codes.

# References


Sutcliffe, J.P. Differential ordering of objects and attributes. Psychometrika, 1986, 51, 209-240.

Nolan, C.Y. and Kederis, C.J. Perceptual Factors in Braille Word Recognition. American Foundation for the Blind Research Series, No. 20. New York: American Foundation for the Blind, 1969.

Foulke, E. Reading braille. In Schiff, W. & Foulke, E. (Eds.), Tactual Perception. Cambridge: Cambridge University Press, 1982.

Geldard, F.A. Introduction: Geldard, F.A. (Ed.) Cutaneous Communication Systems and Devices. Austin,Texas : Psychonomic Society, 1974.

Barnett, M.R. The welfare and training of the blind. In Encyclopaedia Britannica. Chicago : Encyclopaedia Britannica, Inc., 1962

Fertsch, P. Hand dominance in reading braille. American Journal of Psychology, 1947, 60, 335-349.

Bliss, J.C. Reading machines for the blind. In Gordon, G. (Ed.) Active Touch. Oxford : Pergamon Press, 1978.

Kusajima, T. Visual Reading and Braille Reading. New York : American Foundation for the Blind, 1974.

Lappin, J.S. & Foulke, E. expanding the tactual field of view. Perception and Psychophysics, 1973, 14, 237-241.

Békésy, G. von. Human skin perception of travelling waves similar to those of the cochlea. Journal of the Acoustical Society of America, 1955, 27, 830-841.

Gescheider, G.A. Temporal relations in cutaneous stimulation. In Geldard, F.A. (Ed.) Cutaneous Communication Systems and Devices. Austin, Texas : Psychonomic Society, 1974, 33-37.

Holway, A.H. & Crozier, W.J. The significance of area for differential sensitivity in somesthetic pressure. Psychological Record, 1937, 1, 178-184.

Sherrick, C.E. & Craig, J.C. The psychophysics of touch. In Schiff, W. & Foulke, E. (Eds.). Tactual Perception. Cambridge: Cambridge University Press, 1982.

Craig, J.C. & Sherrick, C.E. Dynamic tactile displays. In Schiff, W. & Foulke, E. (Eds.) Tactual Perception. Cambridge: Cambridge University Press, 1982.

Vallbo, A.B. & Johannson, R.S. The tactile sensory innervation of the glabrous skin of the human hand. In Gordon, G. (Ed.) Active Touch. Oxford: Pergamon Press, 1978.

Quilliam, T.A. The structure of finger print skin. In Gordon, G. (Ed.) Active Touch. Oxford: Pergamon Press, 1978.

Nafe, J.P. A quantitative theory of feeling. Journal of General Psychology, 1929, 2, 199-211.

Meyers, E., Ethington, D., & Ashcroft, S. Readability of braille as a function of the spacing variables. Journal of Applied Psychology, 1958, 42, No. 3, 163-165.

Kirman, J.H. Tactile communication of speech. Psychological Bulletin, 1973, 80 No.1, 54-74.

Uniform Type Committee of the American Association of Workers for the Blind. Fifth Biennial Report. Berkeley, California : Convention of Workers for the Blind, 1915.

Kederis, C.J., Siems, J.R. & Haynes, R.L. A frequency count of the symbology of English braille grade 2, American Usage. International Journal for the Education of the Blind, 1965, 15, 38-46.

Millar, S. Tactile short-term memory by blind and sighted children. British Journal of Psychology, 1974, 65, 2, 253-263.

Millar, S. Aspects of memory for information from touch and movement. In Gordon, G. (Ed.) Active Touch. Oxford : Pergamon Press, 1978.

Lederman, S.J. Heightening tactile impressions of surface texture. In Schiff, W. & Foulke, E. (Eds.) Tactual Perception. Cambridge : Cambridge University Press, 1982.

Sakata, H. and Iwamura, Y. Cortical processing of tactile information in the first somatosensory and parietal association areas in the monkey. In Gordon, G. (Ed.) Active Touch. Oxford : Pergamon Press, 1978.

Johnson, K.O. and Lamb, G.D. Neural mechanisms of spatial tactile discrimination: neural patterns evoked by braille- dot patterns in the monkey. Journal of Physiology , 1981, 310, 117-144.

Winer,B.J. Statistical Principles in Experimental Design. New York : McGraw-Hill Book Company, 1971.

## APPENDIX 1

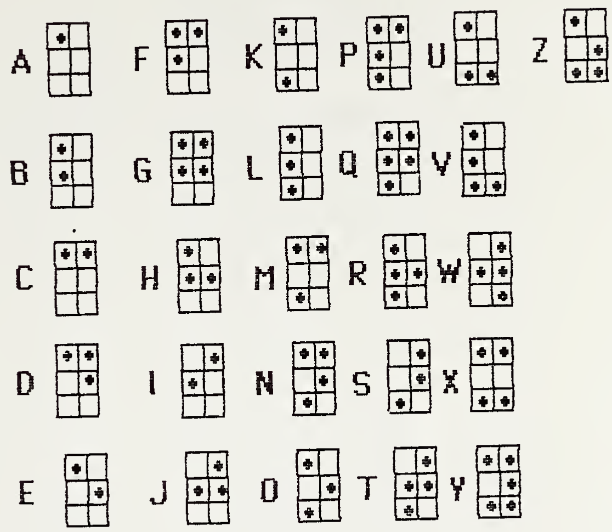
### OBJECTIVE DIFFERENTIATION OF BRAILLE ALPHABET CODES

| | NUMBER OF DIFFERENCES* | RANK ORDER |
|---|---|---|
| W | 93 | 1 |
| I | 78 | 2 |
| J | 78 | 2 |
| U | 78 | 2 |
| Z | 78 | 2 |
| V | 76 | 6 |
| S | 74 | 7 |
| T | 74 | 7 |
| X | 74 | 7 |
| Y | 74 | 7 |
| A | 68 | 11 |
| E | 68 | 11 |
| B | 66 | 13 |
| H | 66 | 13 |
| C | 64 | 15 |
| D | 64 | 15 |
| K | 64 | 15 |
| O | 64 | 15 |
| F | 62 | 19 |
| G | 62 | 19 |
| L | 62 | 19 |
| R | 62 | 19 |
| M | 60 | 23 |
| N | 60 | 23 |
| P | 58 | 25 |
| Q | 58 | 25 |

* Differences in terms of dot/no dot counted across all letters and all positions of the braille matrix.

## APPENDIX 2

## BRAILLE CODES REPRESENTING LETTERS OF THE ALPHABET



Appendix 3

## Objective Differentiation of Braille Matrix Cell Positions for Codes Representing the 26 Letters of the Alphabet

| | Cell Position Rank Orders |
|---|---|
| A | 2=5 3 4 6 1 |
| B | 2=5 4 3 6 1 |
| C | 5 3 4 2 6 1 |
| D | 5 3 4 2 6 1 |
| E | 2=5 3 4 6 1 |
| F | 5 4 3 2 6 1 |
| G | 5 4 3 2 6 1 |
| H | 2=5 4 3 6 1 |
| I | 1 5 4 3 2 6 |
| J | 1 5 4 3 2 6 |
| K | 2 3 4 5 6 1 |
| L | 2 4 3 5 6 1 |
| M | 3 4 2=5 6 1 |
| N | 3 4 2=5 6 1 |
| O | 2 3 4 5 6 1 |
| P | 4 3 2=5 6 1 |
| Q | 4 3 2=5 6 1 |
| R | 2 4 3 5 6 1 |
| S | 1 4 3 2=5 6 |
| T | 1 4 3 2=5 6 |
| U | 6 2 3 4 5 1 |
| V | 6 2 4 3 5 1 |
| W | 1 6 5 4 3 2 |
| X | 6 3 4 2=5 1 |
| Y | 6 3 4 2=5 1 |
| Z | 6 2 3 4 5 1 |
| All Letters | 4 3 2=5 6 1 |

Numbers represent cell positions in the braille matrix (see Page 1 of text for key). Order of cells reads from best differentiating on left to worst differentiating on the right.

## APPENDIX 4

**Comparison of Recognition Time and Objective Difference Rank Orders of Braille Alphabet Codes**

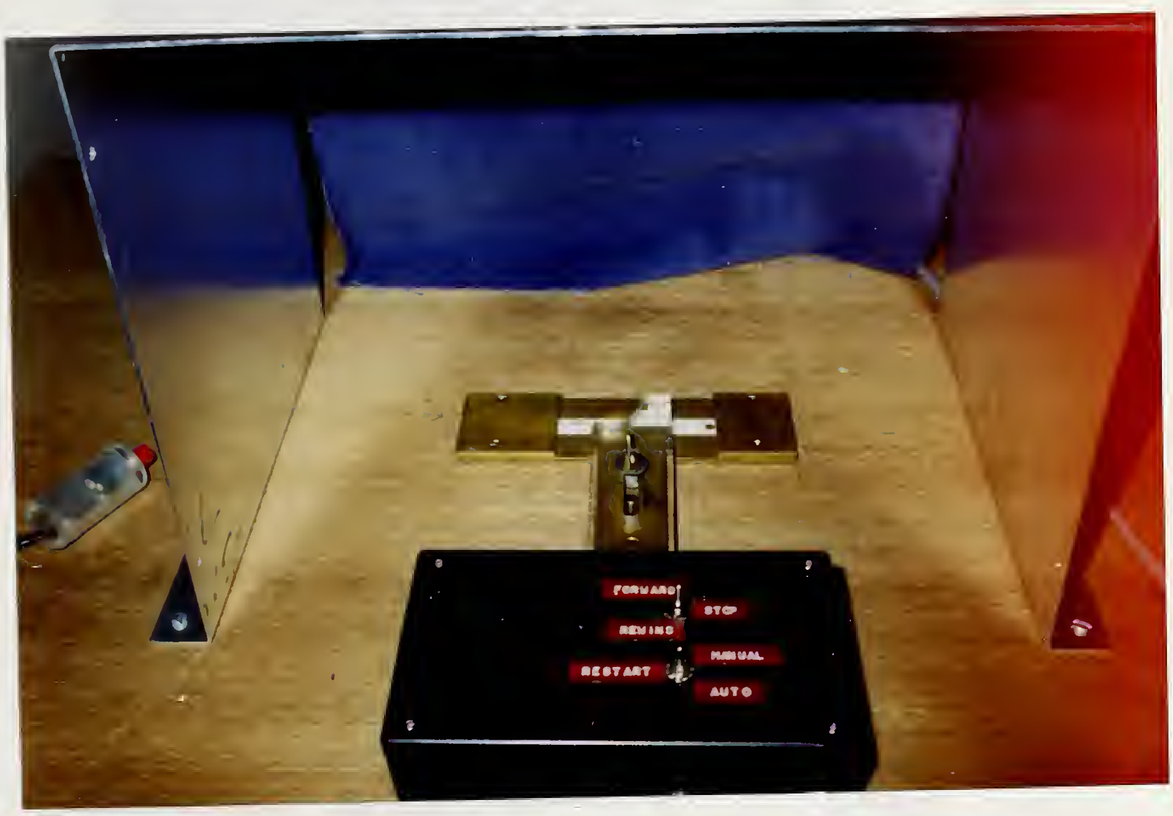
| Letter | Recogn. Time (RT Rank) | Objective Diff. Rank | Letter | Recogn. Time (RT Rank) | Objective Diff. Rank |
|---|---|---|---|---|---|
| E | .02 ( 3) | 11.5 | X | .06 (15.5) | 8.5 |
| A | .02 ( 3) | 11.5 | L | .06 (15.5) | 20.5 |
| I | .02 ( 3) | 3.5 | S | .06 (15.5) | 8.5 |
| C | .02 ( 3) | 16.5 | N | .06 (15.5) | 23.5 |
| K | .02 ( 3) | 16.5 | V | .06 (15.5) | 6 |
| B | .03 ( 6) | 13.5 | F | .07 (19) | 20.5 |
| D | .04 ( 8.5) | 16.5 | Z | .09 (20.5) | 3.5 |
| M | .04 ( 8.5) | 23.5 | Y | .09 (20.5) | 8.5 |
| U | .04 ( 8.5) | 3.5 | P | .10 (22) | 25.5 |
| O | .04 ( 8.5) | 16.5 | W | .11 (23) | 1 |
| J | .05 (11.5) | 3.5 | T | .12 (24) | 8. |
| G | .05 (11.5) | 20.5 | R | .14 (25) | 20.5 |
| H | .06 (15.5) | 13.5 | Q | .18 (26) | 25.5 |

Source : Mean Recognition Times : Nolan and Kederis (1968)
Objective Differentiations : J.P.Sutcliffe (1987)

# APPENDIX 5

## Experimental Apparatus

Tape display surface with shaped guard for sensing finger

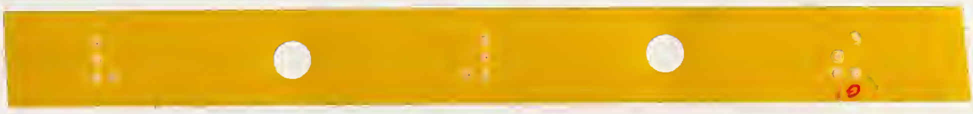



Experimenter's control panel

APPENDIX 5

Experimental Apparatus

Response pad with six keys representing positions in the braille matrix

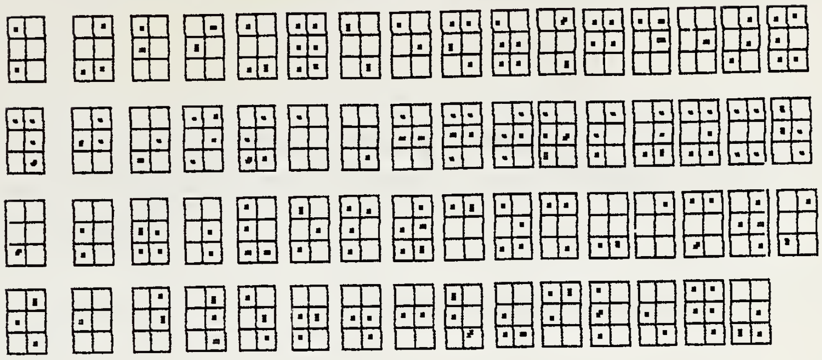


Example of Dymo tape with embossed braille characters

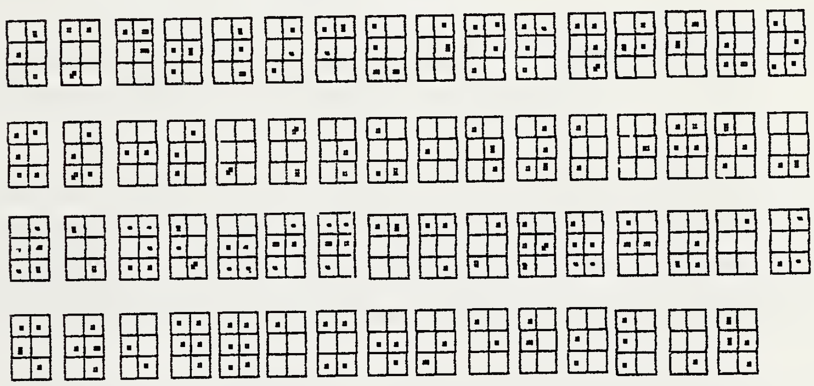
# Appendix 6

## Order of Presentation of Braille Stimuli

### First Presentation Sequence



### Second Presentation Sequence



Order of presentation of both sets of stimulus codes was left to right starting with the top left hand code in each of the above arrays. Presentation sequence in the two sets was based on separate sets of random numbers taken from Tables for Statisticians, Herbert Arkin and Raymond R. Colton, Barnes and Noble Books, New York, 1963.

# Appendix 7

## List of Instructions for Administration of Tests

1. Subject seated comfortably sensing hand in line with finger pad. Subject seated slightly to left of table if right-handed, slightly to the right if right-handed.

2. Index finger positioned on sensing area slightly bent at first joint.

3. With characters visible (curtain lifted) subject's finger is placed in contact with a 6-dot character and positioned to give even contact with all dots in the matrix. Pressure is applied to give an even sense of presence of dot in each dot position.

4. Explain general aims of the experiment : "to test tactual sensitivity of the finger pad at different positions in the matrix".

5. Using manual control run a number of 6-dot characters under the finger to allow the subject to get the feel of the tape and to ensure that even contact is maintained over all positions of the matrix. Repeat until the subject signifies easy apprehension of all dots in the character.

6. Lower the curtain and advance tape to start position between characters 4 and 5 of the code sequence.

7. Run codes 5 through 10 to give the subject the feel of different characters.

8. Advance to position selected randomly between codes 10 and 20. Still on manual advance tape through next 15 characters stopping tape after each code to enable subject to record dots sensed , using the response keyboard.

9. Explain that the machine will now be placed on automatic and that after each character has passed under the finger there will be a pause of 5 seconds to allow recording of responses.

10. Allow subject to proceed through characters 31 to 63 recording dots sensed in each of the 33 codes.

11. Remove response record. Return stimulus display tape to start position.

12. Instruct subject that another series of characters will be run through the machine and that same response procedure should be followed. Tell subjects that codes may be repeated and that they should not be concerned if the same response is recorded more than once.

13. If at any time during training session the subject's responses show evidence of a systematic missing of dots in particular row positions , return to familiarization sequence using six dot characters and follow this by a check using codes at random from the full set. If dots still missed in particular positions this will be assumed to reflect differential sensitivities in the finger pad. Discontinue training and proceed to test proper.

14. The test proper consists of two runs through the code series with a rest of a few minutes between runs. Instruct subjects that code sequences are different from training runs and are different again in the two test runs.

15. Set test apparatus to automatic allowing five seconds delay between presentation of individual codes. Instruct subjects to record response , as in training session , immediately machine stops after each code presentation.

16. Instruct subjects to record a response even if uncertain about dots sensed.

## APPENDIX 8

### THREE DOT BRAILLE CHARACTERS : Dot Number and Dot Position Analysis

**Responses Correctly Reporting Dot Number for Three Dot Braille Characters**

(Base 110 presentations of each character N=37 subjects)

CODES WITH ONE DOT IN FRONT EDGE/ TWO DOTS IN BACK EDGE

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| CODE | DOT NO. CORRECT TOTAL % | DOT NO. CORRECT BOTH COLS. % | DOT POSNS. CORRECT FRONT EDGE % | DOT POSNS. CORRECT BACK EDGE % | CODE CORRECTLY IDENTIFIED % | TWO DOT RESPONSE % | 4 AND 5 DOT RESPONSE % |
| 124 | 56 | 41 | 17 | 24 | 15 | 15 | 25 |
| 234 | 48 | 33 | 22 | 20 | 15 | 23 | 26 |
| 245 | 60 | 40 | 29 | 22 | 12 | 10 | 27 |
| 146 | 70 | 50 | 30 | 31 | 21 | 6 | 25 |
| 346 | 48 | 34 | 20 | 26 | 18 | 17 | 33 |
| 456 | 55 | 32 | 14 | 22 | 11 | 17 | 29 |
| 126 | 55 | 37 | 28 | 18 | 15 | 4 | 39 |
| 236 | 36 | 25 | 19 | 5 | 3 | 3 | 55 |
| 256 | 62 | 31 | 19 | 12 | 8 | 6 | 31 |
| COL. MEANS | 54 | 36 | 22 | 20 | 13 | 11 | 34 |

CODES WITH TWO DOTS IN FRONT EDGE/ ONE DOT BACK EDGE

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| 123 | 52 | 22 | 16 | 14 | 13 | 30 | 16 |
| 134 | 45 | 15 | 12 | 9 | 6 | 21 | 31 |
| 136 | 60 | 21 | 12 | 9 | 6 | 14 | 22 |
| 235 | 53 | 25 | 17 | 13 | 9 | 11 | 34 |
| 345 | 50 | 21 | 14 | 13 | 10 | 22 | 26 |
| 356 | 52 | 23 | 16 | 7 | 7 | 24 | 19 |
| 125 | 45 | 22 | 5 | 11 | 3 | 12 | 34 |
| 145 | 32 | 9 | - | 4 | - | 3 | 63 |
| 156 | 70 | 33 | 14 | 16 | 10 | 6 | 23 |
| COL. MEANS | 51 | 21 | 12 | 11 | 7 | 16 | 30 |

[illegible]

| | |
|---|---|
| 1 | 2 |
| 3 | 4 |
| 5 | 6 |

# APPENDIX 9

SUBJECT PROTOCOLS : ONE AND TWO DOT BRAILLE CODES

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | | | | | | | | | | | |
| 2 | | | | | | | | | | | | |
| 3 | SUBJECT | CODE | | | | | | | R1 | R2 | R3 | |
| 4 | | 1 | 2 | 3 | 4 | 5 | 6 | | 12 | 34 | 56 | |
| 5 | SECOND | | | | | | | | | | | |
| 6 | SERIES CODES | | | | | | | | | | | |
| 7 | | | | | | | | | | | | |
| 8 | MEDINA 1 | 12 | 34 | 35 | 4 | 5 | 3 | | 124 | 56 | 34 | |
| 9 | 2 | 1 | 34 | 3 | 34 | 5 | 5 | | 23 | 34 | 56 | |
| 10 | 3 | 3 | 34 | 3 | 4 | 3 | 35 | | 1234 | 34 | 56 | |
| 11 | | | | | | | | | | | | |
| 12 | JONES 1 | 4 | 1 | 1 | 1 | 5 | 4 | | 34 | 34 | 56 | |
| 13 | 2 | 3 | 2 | 3 | 3 | 4 | 3 | | 12 | 34 | 34 | |
| 14 | 3 | 3 | 2 | 4 | 4 | 5 | 4 | | 12 | 34 | 2 | |
| 15 | | | | | | | | | | | | |
| 16 | FALKINER 1 | 12 | 12 | 35 | 56 | 3 | 3 | | 12 | 13456 | 34 | |
| 17 | 2 | 12 | 14 | 3 | 3 | 35 | 45 | | 12 | 34 | 346 | |
| 18 | 3 | 1 | 1 | 3 | 4 | 3 | 34 | | 12 | 34 | 34 | |
| 19 | | | | | | | | | | | | |
| 20 | FROST 1 | 1 | 2346 | 14 | 34 | 4 | 4 | | 12 | 135 | 13 | |
| 21 | 2 | 1 | 1 | 3 | 36 | 3 | 4 | | 12 | 34 | 35 | |
| 22 | 3 | 12 | 1 | 3 | 4 | 3 | 3 | | 134 | 34 | 346 | |
| 23 | | | | | | | | | | | | |
| 24 | TAN 1 | 1 | 1 | 3 | 4 | 3 | 4 | | 12 | 12 | 34 | |
| 25 | 2 | 1 | 2 | 3 | 2 | 3 | 4 | | 12 | 34 | 34 | |
| 26 | 3 | 2 | 1 | 34 | 4 | 5 | 4 | | 12 | 34 | 56 | |
| 27 | | | | | | | | | | | | |
| 28 | GRANT 1 | 1 | 1 | 3 | 5 | 3 | 6 | | 12 | 134 | 34 | |
| 29 | 2 | 1 | 1 | 6 | 5 | 4 | 5 | | 12 | 13 | 34 | |
| 30 | 3 | 12 | 12 | 6 | 6 | 3 | 5 | | 12 | 4 | 1234 | |
| 31 | | | | | | | | | | | | |
| 32 | PEARSON 1 | 1 | 1 | 3 | 3 | 56 | 34 | | 12 | 12 | 34 | |
| 33 | 2 | 1 | 1 | 4 | 4 | 56 | 35 | | 12 | 34 | 56 | |
| 34 | 3 | 12 | 1 | 3 | 3 | 56 | 5 | | 12 | 5 | 56 | |
| 35 | | | | | | | | | | | | |
| 36 | MOORE 1 | 1 | 1 | 3 | 1 | 5 | 5 | | 1 | 34 | 56 | |
| 37 | 2 | 1 | 1 | 1 | 4 | 5 | 5 | | 2 | 56 | 56 | |
| 38 | 3 | 1 | 1 | 1 | 3 | 5 | 5 | | 12 | 3 | 56 | |
| 39 | | | | | | | | | | | | |
| 40 | DEWAR 1 | 12 | 1 | 3 | 5 | 5 | 5 | | 12 | 56 | 56 | |
| 41 | 2 | 1 | 12 | 5 | 3 | 5 | 6 | | 12 | 56 | 56 | |
| 42 | 3 | 1 | 1 | 3 | 34 | 56 | 5 | | 12 | 234 | 23456 | |
| 43 | | | | | | | | | | | | |
| 44 | WATMAN 1 | 1 | 1 | 34 | 4 | 5 | 46 | | 12 | 34 | 456 | |
| 45 | 2 | 2 | 12 | 3 | 4 | 56 | 3 | | 12 | 34 | 456 | |
| 46 | 3 | 12 | 1 | 34 | 4 | 5 | 3 | | 12 | 34 | 456 | |
| 47 | | | | | | | | | | | | |
| 48 | STRAIN 1 | 1 | 12 | 1 | 4 | 5 | 456 | | 12 | 456 | 56 | |
| 49 | 2 | 1 | 1 | 6 | 4 | 6 | 5 | | 12 | 46 | 34 | |
| 50 | 3 | 1 | 1 | 3 | 3 | 5 | 5 | | 12 | 3 | 35 | |
| 51 | | | | | | | | | | | | |
| 52 | FABIAN 1 | 1 | 1 | 3 | 5 | 5 | 5 | | 12 | 34 | 56 | |
| 53 | 2 | 1 | 1 | 3 | 35 | 3 | 5 | | 1 | 456 | 56 | |
| 54 | 3 | 34 | 1 | 3 | 4 | 5 | 34 | | 12 | 345 | 56 | |
| 55 | | | | | | | | | | | | |
| 56 | | | | | | | | | | | | |
| 57 | | | | | | | | | | | | |

# APPENDIX 9

| | |
|---|---|
| 1 | 2 |
| 3 | 4 |
| 5 | 6 |

SUBJECT PROTOCOLS : ONE AND TWO DOT BRAILLE CODES

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 58 | | | | | | | | | | | | |
| 59 | | | | | | | | | | | | |
| 60 | | | | | | | | | | | | |
| 61 | SUBJECT | CODE | | | | | | | R1 | R2 | R3 | |
| 62 | | 1 | 2 | 3 | 4 | 5 | 6 | | 12 | 34 | 56 | |
| 63 | | | | | | | | | | | | |
| 64 | SHARP 1 | 1 | 1 | 3 | 3 | 5 | 4 | | 12 | 4 | 56 | |
| 65 | 2 | 1 | 3 | 3 | 3 | 6 | 6 | | 12 | 34 | 34 | |
| 66 | 3 | 3 | 1 | 3 | 4 | 4 | 6 | | 2 | 34 | 56 | |
| 67 | | | | | | | | | | | | |
| 68 | PERIC 1 | 3 | 3 | 3 | 3 | 3 | 3 | | 34 | 3 | 34 | |
| 69 | 2 | 4 | 2 | 3 | 3 | 3 | 3 | | 34 | 34 | 34 | |
| 70 | 3 | 1 | 3 | 4 | 4 | 3 | 4 | | 12 | 34 | 34 | |
| 71 | | | | | | | | | | | | |
| 72 | BERNOTAS 1 | 5 | 1 | 5 | 3 | 5 | 3 | | 24 | 56 | 3 | |
| 73 | 2 | 1 | 4 | 3 | 4 | 5 | 3 | | 12 | 3 | 2346 | |
| 74 | 3 | 5 | 2 | 34 | 3 | 56 | 5 | | 2 | 56 | 345 | |
| 75 | | | | | | | | | | | | |
| 76 | TURNER 1 | 1 | 1 | 1 | 4 | 5 | 6 | | 12 | 56 | 456 | |
| 77 | 2 | 1 | 1 | 1 | 3 | 3 | 6 | | 12 | 34 | 46 | |
| 78 | 3 | 12 | 1 | 2 | 3 | 6 | 5 | | 12 | 34 | 6 | |
| 79 | | | | | | | | | | | | |
| 80 | 1st SERIES | | | | | | | | | | | |
| 81 | CODES | | | | | | | | | | | |
| 82 | | | | | | | | | | | | |
| 83 | MOLLISON 1 | 3 | 4 | 5 | 3 | 3 | 56 | | 346 | 56 | 56 | |
| 84 | 2 | 3 | 34 | 5 | 56 | 5 | 5 | | 1234 | 34 | 34 | |
| 85 | 3 | 4 | 4 | 5 | 34 | 3 | 34 | | 124 | 56 | 56 | |
| 86 | | | | | | | | | | | | |
| 87 | BRIGGS 1 | 4 | 1 | 4 | 4 | 6 | 6 | | 234 | 23 | 34 | |
| 88 | 2 | 234 | 4 | 4 | 3 | 6 | 6 | | 1234 | 34 | 34 | |
| 89 | 3 | 2 | 36 | 4 | 4 | 6 | 6 | | 234 | 234 | 3 | |
| 90 | | | | | | | | | | | | |
| 91 | HELLYAR 1 | 1 | 2 | 34 | 3 | 345 | 34 | | 123 | 123 | 34 | |
| 92 | 2 | 2 | 1 | 3 | 3 | 34 | 3 | | 12 | 34 | 34 | |
| 93 | 3 | 2 | 1 | 3 | 3 | 345 | 45 | | 12 | 34 | 345 | |
| 94 | | | | | | | | | | | | |
| 95 | CAMPION 1 | 134 | 46 | 34 | 34 | 5 | 5 | | 12 | 34 | 34 | |
| 96 | 2 | 1 | 34 | 34 | 46 | 5 | 3 | | 1234 | 34 | 34 | |
| 97 | 3 | 2 | 34 | 3 | 46 | 6 | 3 | | 34 | 34 | 34 | |
| 98 | | | | | | | | | | | | |
| 99 | BAGHOM 1 | 12 | 1 | 1 | 4 | 5 | 3 | | 12 | 12 | 34 | |
| 100 | 2 | 1 | 2 | 3 | 1 | 5 | 5 | | 12 | 12 | 56 | |
| 101 | 3 | 1 | 1 | 3 | 3 | 5 | 5 | | 12 | 12 | 56 | |
| 102 | | | | | | | | | | | | |
| 103 | HARRISON 1 | 1 | 23 | 3 | 4 | 5 | 5 | | 12 | 56 | 456 | |
| 104 | 2 | 2 | 2 | 3 | 5 | 5 | 3 | | 12 | 34 | 456 | |
| 105 | 3 | 12 | 1 | 1 | 3 | 6 | 4 | | 12 | 124 | 2456 | |
| 106 | | | | | | | | | | | | |
| 107 | VALLING 1 | 2 | 1 | 3 | 5 | 5 | 5 | | 2 | 124 | 34 | |
| 108 | 2 | 1 | 2 | 34 | 4 | 5 | 5 | | 246 | 234 | 346 | |
| 109 | 3 | 1 | 12 | 6 | 3 | 5 | 5 | | 2 | 124 | 5 | |
| 110 | | | | | | | | | | | | |
| 111 | FROST 1 | 2 | 1 | 1 | 3 | 5 | 5 | | 12 | 124 | 34 | |
| 112 | 2 | 4 | 1 | 3 | 3 | 5 | 5 | | 12 | 56 | 56 | |
| 113 | 3 | 1 | 1 | 3 | 3 | 5 | 5 | | 12 | 56 | 56 | |
| 114 | | | | | | | | | | | | |

| | |
|---|---|
| 1 | 2 |
| 3 | 4 |
| 5 | 6 |

# APPENDIX 9

SUBJECT PROTOCOLS : ONE AND TWO DOT BRAILLE CODES

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 115 | | | | | | | | | | | | |
| 116 | SUBJECT | CODE | | | | | | | R1 | R2 | R3 | |
| 117 | | 1 | 2 | 3 | 4 | 5 | 6 | | 12 | 34 | 56 | |
| 118 | | | | | | | | | | | | |
| 119 | COOPER 1 | 1 | 1 | 3 | 4 | 5 | 3 | | 12 | 34 | 34 | |
| 120 | 2 | 1 | 1 | 3 | 4 | 5 | 6 | | 13 | 34 | 34 | |
| 121 | 3 | 1 | 1 | 3 | 3 | 5 | 4 | | 12 | 34 | 56 | |
| 122 | | | | | | | | | | | | |
| 123 | | | | | | | | | | | | |
| 124 | MARSH 1 | 2 | 24 | 3 | 3 | 5 | 5 | | 234 | 346 | 45 | |
| 125 | 2 | 2 | 1 | 4 | 3 | 5 | 5 | | 1 | 34 | 6 | |
| 126 | 3 | 2 | 12 | 45 | 6 | 5 | 5 | | 1234 | 234 | 456 | |
| 127 | | | | | | | | | | | | |
| 128 | NIX 1 | 1 | 1 | 3 | 3 | 56 | 5 | | 12 | 34 | 56 | |
| 129 | 2 | 1 | 12 | 3 | 46 | 5 | 5 | | 134 | 34 | 456 | |
| 130 | 3 | 1 | 1 | 1 | 46 | 5 | 5 | | 12 | 34 | 456 | |
| 131 | | | | | | | | | | | | |
| 132 | BOADLE 1 | 1 | 2 | 46 | 4 | 5 | 6 | | 12 | 124 | 34 | |
| 133 | 2 | 2 | 1 | 2 | 6 | 6 | 6 | | 2 | 34 | 6 | |
| 134 | 3 | 1 | 2 | 3 | 2 | 6 | 6 | | 12 | 12 | 4 | |
| 135 | | | | | | | | | | | | |
| 136 | BOUZEID 1 | 1 | 1 | 35 | 3 | 5 | 5 | | 12 | 34 | 14 | |
| 137 | 2 | 1 | 1 | 3 | 3 | 5 | 4 | | 12 | 12 | 34 | |
| 138 | 3 | 12 | 12 | 4 | 3 | 5 | 5 | | 1 | 234 | 3 | |
| 139 | | | | | | | | | | | | |
| 140 | JORQUE 1 | 1 | 1 | 13 | 3 | 3 | 3 | | 1234 | 12 | 34 | |
| 141 | 2 | 2 | 1 | 3 | 3 | 5 | 5 | | 12 | 34 | 3 | |
| 142 | 3 | 1 | 2 | 3 | 1 | 5 | 3 | | 12 | 34 | 34 | |
| 143 | | | | | | | | | | | | |
| 144 | DUNN 1 | 1 | 4 | 34 | 3 | 56 | 3 | | 12 | 34 | 34 | |
| 145 | 2 | 3 | 1 | 34 | 3 | 34 | 5 | | 12 | 36 | 346 | |
| 146 | 3 | 1 | 2 | 34 | 3 | 3 | 3 | | 1 | 56 | 34 | |
| 147 | | | | | | | | | | | | |
| 148 | SPORA 1 | 1 | 2 | 6 | 4 | 4 | 4 | | 12 | 34 | 34 | |
| 149 | 2 | 12 | 12 | 56 | 4 | 6 | 2 | | 34 | 34 | 56 | |
| 150 | 3 | 1 | 2 | 4 | 3 | 3 | 5 | | 12 | 34 | 56 | |
| 151 | | | | | | | | | | | | |
| 152 | ZAGORSKI 1 | 23 | 3 | 1 | 4 | 5 | 3 | | 12 | 34 | 56 | |
| 153 | 2 | 1 | 34 | 36 | 1 | 5 | 5 | | 12 | 24 | 356 | |
| 154 | 3 | 1 | 12 | 3 | 5 | 5 | 56 | | 345 | 3 | 56 | |
| 155 | | | | | | | | | | | | |
| 156 | NGUYEN 1 | 24 | 1 | 35 | 4 | 4 | 4 | | 12 | 24 | 34 | |
| 157 | 2 | 2 | 2 | 12 | 3 | 4 | 4 | | 12 | 12 | 34 | |
| 158 | 3 | 2 | 2 | 4 | 4 | 6 | 1 | | 12 | 12 | 34 | |
| 159 | | | | | | | | | | | | |
| 160 | GRIFFITHS 1 | 14 | 1 | 5 | 1 | 3 | 3 | | 12 | 34 | 34 | |
| 161 | 2 | 16 | 3 | 3 | 3 | 56 | 5 | | 12 | 134 | 346 | |
| 162 | 3 | 3 | 2 | 3 | 3 | 34 | 3 | | 14 | 13 | 346 | |
| 163 | | | | | | | | | | | | |
| 164 | LARKIN 1 | 1 | 1 | 3 | 3 | 3 | 3 | | 1 | 3 | 36 | |
| 165 | 2 | 1 | 14 | 3 | 3 | 34 | 3 | | 23 | 34 | 3 | |
| 166 | 3 | 12 | 1 | 3 | 3 | 5 | 3 | | 23 | 12 | 3 | |
| 167 | | | | | | | | | | | | |
| 168 | MCCRAN 1 | 12 | 2 | 3 | 3 | 4 | 5 | | 2 | 56 | 4 | |
| 169 | 2 | 2 | 2 | 2 | 3 | 5 | 5 | | 1 | 13 | 3 | |
| 170 | | | | | | | | | | | | |
| 171 | | | | | | | | | | | | |

# APPENDIX 9

SUBJECT PROTOCOLS : ONE AND TWO DOT BRAILLE CODES

| | |
|---|---|
| 1 | 2 |
| 3 | 4 |
| 5 | 6 |

| | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | | | | | | | | | |
| 2 | | | | | | | | | | |
| 3 | | SV1 | SV2 | SV3 | SV4 | SD1 | SD2 | SD3 | SD4 | |
| 4 | CODE | 13 | 24 | 35 | 46 | 14 | 23 | 36 | 45 | |
| 5 | SECOND | | | | | | | | | |
| 6 | SERIES CODES | | | | | | | | | |
| 7 | | | | | | | | | | |
| 8 | MEDINA 1 | 13 | 35 | 35 | 4 | 356 | 234 | 46 | 34 | |
| 9 | 2 | 35 | 35 | 35 | 35 | 36 | 345 | 136 | 456 | |
| 10 | 3 | 135 | 35 | 35 | 35 | 146 | 245 | 356 | 245 | |
| 11 | | | | | | | | | | |
| 12 | JONES 1 | 24 | 14 | 24 | 14 | 13 | 135 | 145 | 34 | |
| 13 | 2 | 14 | 3 | 23 | 24 | 12 | 23 | 125 | 23 | |
| 14 | 3 | 34 | 2 | 13 | 34 | 14 | 12 | 35 | 23 | |
| 15 | | | | | | | | | | |
| 16 | FALKINER 1 | 124 | 12345 | 124 | 3456 | 12 | 234 | 134 | 1235 | |
| 17 | 2 | 23 | 134 | 235 | 35 | 12 | 134 | 234 | 1345 | |
| 18 | 3 | 134 | 1235 | 3 | 1456 | 34 | 23 | 12 | 234 | |
| 19 | | | | | | | | | | |
| 20 | FROST 1 | 124 | 1246 | 46 | 46 | 134 | 1346 | 1456 | 134 | |
| 21 | 2 | 124 | 46 | 1246 | 35 | 124 | 1346 | 134 | 134 | |
| 22 | 3 | 146 | 35 | 46 | 35 | 1246 | 1345 | 346 | 146 | |
| 23 | | | | | | | | | | |
| 24 | TAN 1 | 23 | 14 | 24 | 35 | 124 | 234 | 146 | 245 | |
| 25 | 2 | 24 | 14 | 24 | 3 | 12 | 235 | 134 | 23 | |
| 26 | 3 | 24 | 1 | 13 | 35 | 134 | 23 | 346 | 23 | |
| 27 | | | | | | | | | | |
| 28 | GRANT 1 | 24 | 34 | 456 | 3 | 12 | 24 | 56 | 245 | |
| 29 | 2 | 13 | 12 | 35 | 46 | 126 | 124 | 34 | 245 | |
| 30 | 3 | 12 | 35 | 34 | 46 | 12 | 2345 | 346 | 245 | |
| 31 | | | | | | | | | | |
| 32 | PEARSON 1 | 12 | 12 | 34 | 34 | 124 | 23 | 34 | 346 | |
| 33 | 2 | 24 | 24 | 35 | 56 | 136 | 23 | 34 | 245 | |
| 34 | 3 | 3 | 234 | 35 | 3 | 345 | 23 | 234 | 356 | |
| 35 | | | | | | | | | | |
| 36 | MOORE 1 | 345 | 123 | 35 | 5 | 124 | 234 | 14 | 45 | |
| 37 | 2 | 24 | 1 | 46 | 35 | 124 | 45 | 36 | 23 | |
| 38 | 3 | 23 | 12 | 46 | 35 | 124 | 23 | 36 | 45 | |
| 39 | | | | | | | | | | |
| 40 | DEWAR 1 | 5 | 56 | 56 | 456 | 146 | 124 | 346 | 346 | |
| 41 | 2 | 6 | 34 | 46 | 6 | 1234 | 456 | 36 | 346 | |
| 42 | 3 | 1246 | 124 | 346 | 2456 | 124 | 12 | 1236 | 2346 | |
| 43 | | | | | | | | | | |
| 44 | WATMAN 1 | 124 | 12 | 24 | 34 | 12 | 13 | 346 | 235 | |
| 45 | 2 | 24 | 35 | 34 | 56 | 124 | 234 | 2346 | 45 | |
| 46 | 3 | 13 | 13 | 35 | 35 | 124 | 23 | 346 | 123 | |
| 47 | | | | | | | | | | |
| 48 | STRAIN 1 | 123 | 4 | 56 | 35 | 12 | 126 | 46 | 34 | |
| 49 | 2 | 2 | 24 | 36 | 56 | 24 | 2346 | 56 | 35 | |
| 50 | 3 | 1 | 35 | 34 | 5 | 34 | 13 | 235 | 345 | |
| 51 | | | | | | | | | | |
| 52 | FABIAN 1 | 34 | 46 | 34 | 56 | 146 | 45 | 345 | 45 | |
| 53 | 2 | 13 | 3 | 35 | 45 | 236 | 46 | 56 | 26 | |
| 54 | 3 | 35 | 34 | 35 | 35 | 14 | 15 | 236 | 15 | |
| 55 | | | | | | | | | | |
| 56 | | | | | | | | | | |
| 57 | | | | | | | | | | |

## APPENDIX 9

SUBJECT PROTOCOLS : ONE AND TWO DOT BRAILLE CODES

| | |
|---|---|
| 1 | 2 |
| 3 | 4 |
| 5 | 6 |

| | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 |
|---|---|---|---|---|---|---|---|---|---|---|
| 58 | | | | | | | | | | |
| 59 | | | | | | | | | | |
| 60 | | | | | | | | | | |
| 61 | | SV1 | SV2 | SV3 | SV4 | SD1 | SD2 | SD3 | SD4 | |
| 62 | | 13 | 24 | 35 | 46 | 14 | 23 | 36 | 45 | |
| 63 | | | | | | | | | | |
| 64 | SHARP 1 | 36 | 3 | 56 | 34 | 36 | 56 | 36 | 45 | |
| 65 | 2 | 25 | 3 | 34 | 46 | 346 | 23 | 36 | 34 | |
| 66 | 3 | 56 | 12 | 56 | 46 | 56 | 34 | 34 | 245 | |
| 67 | | | | | | | | | | |
| 68 | PERIC 1 | 46 | 24 | 46 | 13 | 34 | 24 | 34 | 35 | |
| 69 | 2 | 35 | 35 | 46 | 35 | 346 | 35 | 346 | 13 | |
| 70 | 3 | 24 | 35 | 24 | 4 | 34 | 35 | 34 | 24 | |
| 71 | | | | | | | | | | |
| 72 | BERNOTAS 1 | 34 | 5 | 35 | 45 | 12 | 34 | 56 | 345 | |
| 73 | 2 | 23 | 35 | 35 | 35 | 234 | 34 | 245 | 245 | |
| 74 | 3 | 34 | 56 | 345 | 345 | 346 | 34 | 456 | 13456 | |
| 75 | | | | | | | | | | |
| 76 | TURNER 1 | 14 | 46 | 34 | 46 | 12 | 4 | 124 | 456 | |
| 77 | 2 | 1 | 46 | 46 | 13 | 136 | 46 | 146 | 13 | |
| 78 | 3 | 35 | 4 | 35 | 24 | 146 | 3 | 136 | 45 | |
| 79 | | | | | | | | | | |
| 80 | 1st SERIES | | | | | | | | | |
| 81 | CODES | | | | | | | | | |
| 82 | | | | | | | | | | |
| 83 | MOLLISON 1 | 35 | 56 | 34 | 34 | 124 | 35 | 34 | 56 | |
| 84 | 2 | 56 | 56 | 3456 | 246 | 34 | 35 | 346 | 56 | |
| 85 | 3 | 5 | 56 | 3456 | 135 | 34 | 34 | 456 | 246 | |
| 86 | | | | | | | | | | |
| 87 | BRIGGS 1 | 346 | 24 | 56 | 46 | 245 | 234 | 346 | 456 | |
| 88 | 2 | 26 | 4 | 36 | 36 | 146 | 234 | 346 | 145 | |
| 89 | 3 | 346 | 24 | 56 | 56 | 346 | 34 | 346 | 346 | |
| 90 | | | | | | | | | | |
| 91 | HELLYAR 1 | 123 | 24 | 356 | 13456 | 123 | 23 | 13 | 23 | |
| 92 | 2 | 34 | 24 | 356 | 345 | 146 | 23 | 126 | 45 | |
| 93 | 3 | 123 | 13 | 3456 | 345 | 14 | 23 | 235 | 345 | |
| 94 | | | | | | | | | | |
| 95 | CAMPION 1 | 34 | 12346 | 346 | 3456 | 134 | 34 | 56 | 134 | |
| 96 | 2 | 24 | 1246 | 134 | 3456 | 1246 | 246 | 46 | 346 | |
| 97 | 3 | 24 | 346 | 34 | 34 | 246 | 4 | 46 | 46 | |
| 98 | | | | | | | | | | |
| 99 | BAGHOM 1 | 124 | 12 | 34 | 34 | 146 | 146 | 3 | 346 | |
| 100 | 2 | 35 | 12 | 5 | 34 | 36 | 235 | 36 | 345 | |
| 101 | 3 | 12 | 1 | 3 | 56 | 346 | 23 | 14 | 34 | |
| 102 | | | | | | | | | | |
| 103 | HARRISON 1 | 123 | 2 | 34 | 12 | 14 | 345 | 36 | 45 | |
| 104 | 2 | 46 | 13 | 56 | 3 | 236 | 23 | 23 | 45 | |
| 105 | 3 | 46 | 13 | 3 | 4 | 234 | 23 | 245 | 345 | |
| 106 | | | | | | | | | | |
| 107 | VALLING 1 | 124 | 124 | 35 | 3 | 1246 | 24 | 456 | 245 | |
| 108 | 2 | 124 | 234 | 3456 | 345 | 124 | 245 | 1236 | 346 | |
| 109 | 3 | 24 | 23 | 24 | 1246 | 24 | 124 | 345 | 234 | |
| 110 | | | | | | | | | | |
| 111 | FROST 1 | 34 | 12 | 35 | 12 | 14 | 124 | 36 | 36 | |
| 112 | 2 | 124 | 1 | 1 | 2 | 124 | 124 | 35 | 56 | |
| 113 | 3 | 24 | 124 | 3 | 36 | 124 | 24 | 14 | 35 | |
| 114 | | | | | | | | | | |

# APPENDIX 9

SUBJECT PROTOCOLS : ONE AND TWO DOT BRAILLE CODES

| | |
|---|---|
| 1 | 2 |
| 3 | 4 |
| 5 | 6 |

| | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 |
|---|---|---|---|---|---|---|---|---|---|---|
| 115 | | | | | | | | | | |
| 116 | | SV1 | SV2 | SV3 | SV4 | SD1 | SD2 | SD3 | SD4 | |
| 117 | CODE | 13 | 24 | 35 | 46 | 14 | 23 | 36 | 45 | |
| 118 | | | | | | | | | | |
| 119 | COOPER 1 | 34 | 134 | 35 | 35 | 12 | 234 | 123 | 245 | |
| 120 | 2 | 13 | 24 | 35 | 4 | 12 | 123 | 346 | 456 | |
| 121 | 3 | 13 | 14 | 3 | 45 | 346 | 234 | 346 | 245 | |
| 122 | | | | | | | | | | |
| 123 | | | | | | | | | | |
| 124 | MARSH 1 | 134 | 124 | 456 | 35 | 124 | 24 | 36 | 45 | |
| 125 | 2 | 346 | 234 | 26 | 46 | 14 | 23 | 1346 | 456 | |
| 126 | 3 | 346 | 34 | 46 | 13456 | 23 | 234 | 46 | 56 | |
| 127 | | | | | | | | | | |
| 128 | NIX 1 | 35 | 234 | 35 | 35 | 34 | 34 | 346 | 56 | |
| 129 | 2 | 45 | 2346 | 35 | 35 | 124 | 35 | 345 | 3456 | |
| 130 | 3 | 46 | 13 | 35 | 5 | 34 | 346 | 14 | 56 | |
| 131 | | | | | | | | | | |
| 132 | BOADLE 1 | 4 | 12 | 6 | 345 | 14 | 346 | 346 | 46 | |
| 133 | 2 | 46 | 24 | 46 | 46 | 12 | 456 | 4 | 46 | |
| 134 | 3 | 46 | 2 | 46 | 46 | 12 | 46 | 346 | 45 | |
| 135 | | | | | | | | | | |
| 136 | BOUZEID 1 | 12 | 135 | 3 | 34 | 124 | 14 | 13 | 56 | |
| 137 | 2 | 14 | 1 | 35 | 345 | 14 | 1234 | 124 | 34 | |
| 138 | 3 | 14 | 34 | 3 | 35 | 12 | 234 | 14 | 356 | |
| 139 | | | | | | | | | | |
| 140 | JORQUE 1 | 35 | 13 | 35 | 13 | 356 | 45 | 12 | 45 | |
| 141 | 2 | 13 | 13 | 24 | 46 | 1346 | 45 | 14 | 25 | |
| 142 | 3 | 13 | 13 | 34 | 13 | 14 | 123 | 136 | 45 | |
| 143 | | | | | | | | | | |
| 144 | DUNN 1 | 34 | 12 | 56 | 34 | 34 | 234 | 134 | 234 | |
| 145 | 2 | 36 | 12 | 45 | 45 | 346 | 346 | 2346 | 34 | |
| 146 | 3 | 346 | 3 | 34 | 234 | 36 | 36 | 346 | 236 | |
| 147 | | | | | | | | | | |
| 148 | SPORA 1 | 34 | 3 | 46 | 6 | 34 | 346 | 24 | 46 | |
| 149 | 2 | 46 | 36 | 6 | 6 | 136 | 24 | 23 | 34 | |
| 150 | 3 | 35 | 12 | 34 | 34 | 134 | 46 | 24 | 56 | |
| 151 | | | | | | | | | | |
| 152 | ZAGORSKI 1 | 45 | 13 | 36 | 34 | 134 | 234 | 36 | 234 | |
| 153 | 2 | 35 | 34 | 45 | 35 | 136 | 346 | 36 | 456 | |
| 154 | 3 | 12 | 134 | 45 | 46 | 16 | 35 | 16 | 45 | |
| 155 | | | | | | | | | | |
| 156 | NGUYEN 1 | 24 | 4 | 46 | 35 | 24 | 24 | 34 | 34 | |
| 157 | 2 | 234 | 24 | 24 | 24 | 24 | 24 | 46 | 34 | |
| 158 | 3 | 24 | 2 | 56 | 46 | 24 | 23 | 24 | 23 | |
| 159 | | | | | | | | | | |
| 160 | GRIFFITHS 1 | 35 | 34 | 3 | 23 | 123 | 45 | 35 | 45 | |
| 161 | 2 | 34 | 346 | 45 | 3 | 234 | 345 | 135 | 2456 | |
| 162 | 3 | 13 | 346 | 34 | 35 | 134 | 1234 | 34 | 345 | |
| 163 | | | | | | | | | | |
| 164 | LARKIN 1 | 34 | 34 | 13 | 123 | 23 | 23 | 34 | 23 | |
| 165 | 2 | 34 | 12 | 234 | 234 | 346 | 234 | 234 | 23 | |
| 166 | 3 | 3 | 234 | 346 | 34 | 34 | 34 | 124 | 12 | |
| 167 | | | | | | | | | | |
| 168 | MCCRAN 1 | 5 | 2 | 13 | 12 | 4 | 345 | 56 | 13 | |
| 169 | 2 | 5 | 2 | 3 | 5 | 25 | 35 | 13 | 1 | |
| 170 | | | | | | | | | | |
| 171 | | | | | | | | | | |

## APPENDIX 9

SUBJECT PROTOCOLS : ONE AND TWO DOT BRAILLE CODES

| | |
|---|---|
| 1 | 2 |
| 3 | 4 |
| 5 | 6 |

| | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 |
|---|---|---|---|---|---|---|---|---|---|
| 1 | | | | | | | | | |
| 2 | | | | | | | | | |
| 3 | | SUBJECT | | LV1 | LV2 | LD1 | LD2 | | |
| 4 | | | CODE | 15 | 26 | 16 | 25 | | |
| 5 | | SECOND | | | | | | | |
| 6 | | SERIES CODES | | | | | | | |
| 7 | | | | | | | | | |
| 8 | | MEDINA 1 | | 135 | 35 | 345 | 256 | | |
| 9 | | 2 | | 235 | 135 | 126 | 235 | | |
| 10 | | 3 | | 135 | 245 | 136 | 235 | | |
| 11 | | | | | | | | | |
| 12 | | JONES 1 | | 15 | 15 | 245 | 16 | | |
| 13 | | 2 | | 13 | 14 | 146 | 25 | | |
| 14 | | 3 | | 245 | 26 | 13 | 25 | | |
| 15 | | | | | | | | | |
| 16 | | FALKINER 1 | | 356 | 1345 | 134 | 12 | | |
| 17 | | 2 | | 12456 | 236 | 123 | 134 | | |
| 18 | | 3 | | 124 | 145 | 124 | 134 | | |
| 19 | | | | | | | | | |
| 20 | | FROST 1 | | 1346 | 1246 | 146 | 16 | | |
| 21 | | 2 | | 136 | 16 | 346 | 16 | | |
| 22 | | 3 | | 246 | 15 | 136 | 15 | | |
| 23 | | | | | | | | | |
| 24 | | TAN 1 | | 26 | 23 | 16 | 15 | | |
| 25 | | 2 | | 16 | 16 | 16 | 25 | | |
| 26 | | 3 | | 16 | 15 | 16 | 25 | | |
| 27 | | | | | | | | | |
| 28 | | GRANT 1 | | 135 | 135 | 1346 | 1235 | | |
| 29 | | 2 | | 135 | 46 | 1346 | 1346 | | |
| 30 | | 3 | | 1246 | 35 | 12346 | 1345 | | |
| 31 | | | | | | | | | |
| 32 | | PEARSON 1 | | 135 | 145 | 124 | 126 | | |
| 33 | | 2 | | 234 | 24 | 124 | 1245 | | |
| 34 | | 3 | | 26 | 26 | 236 | 23 | | |
| 35 | | | | | | | | | |
| 36 | | MOORE 1 | | 16 | 15 | 16 | 125 | | |
| 37 | | 2 | | 24 | 156 | 16 | 25 | | |
| 38 | | 3 | | 156 | 156 | 16 | 125 | | |
| 39 | | | | | | | | | |
| 40 | | DEWAR 1 | | 2456 | 256 | 26 | 245 | | |
| 41 | | 2 | | 236 | 26 | 14 | 126 | | |
| 42 | | 3 | | 1246 | 245 | 126 | 126 | | |
| 43 | | | | | | | | | |
| 44 | | WATMAN 1 | | 1235 | 26 | 16 | 245 | | |
| 45 | | 2 | | 2456 | 126 | 126 | 1356 | | |
| 46 | | 3 | | 246 | 135 | 146 | 456 | | |
| 47 | | | | | | | | | |
| 48 | | STRAIN 1 | | 234 | 356 | 124 | 1256 | | |
| 49 | | 2 | | 46 | 35 | 25 | 245 | | |
| 50 | | 3 | | 135 | 345 | 125 | 1245 | | |
| 51 | | | | | | | | | |
| 52 | | FABIAN 1 | | 135 | 246 | 145 | 15 | | |
| 53 | | 2 | | 15 | 256 | 3456 | 245 | | |
| 54 | | 3 | | 146 | 15 | 126 | 25 | | |
| 55 | | | | | | | | | |
| 56 | | | | | | | | | |
| 57 | | | | | | | | | |

# APPENDIX 9

SUBJECT PROTOCOLS : ONE AND TWO DOT BRAILLE CODES

| 1 | 2 |
|---|---|
| 3 | 4 |
| 5 | 6 |

| | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 |
|---|---|---|---|---|---|---|---|---|---|
| 58 | | | | | | | | | |
| 59 | | | | | | | | | |
| 60 | | SUBJECT | | LV1 | LV2 | LD1 | LD2 | | |
| 61 | | | CODE | 15 | 26 | 16 | 25 | | |
| 62 | | | | | | | | | |
| 63 | | | | | | | | | |
| 64 | | SHARP 1 | | 245 | 45 | 136 | 245 | | |
| 65 | | 2 | | 135 | 456 | 145 | 125 | | |
| 66 | | 3 | | 245 | 46 | 245 | 45 | | |
| 67 | | | | | | | | | |
| 68 | | PERIC 1 | | 24 | 13 | 36 | 45 | | |
| 69 | | 2 | | 346 | 36 | 14 | 15 | | |
| 70 | | 3 | | 26 | 23 | 236 | 26 | | |
| 71 | | | | | | | | | |
| 72 | | BERNOTAS 1 | | 135 | 345 | 234 | 235 | | |
| 73 | | 2 | | 136 | 5 | 234 | 25 | | |
| 74 | | 3 | | 235 | 456 | 2345 | 245 | | |
| 75 | | | | | | | | | |
| 76 | | TURNER 1 | | 13 | 45 | 146 | 46 | | |
| 77 | | 2 | | 24 | 15 | 16 | 26 | | |
| 78 | | 3 | | 26 | 15 | 136 | 15 | | |
| 79 | | | | | | | | | |
| 80 | | 1st SERIES | | | | | | | |
| 81 | | CODES | | | | | | | |
| 82 | | | | | | | | | |
| 83 | | MOLLISON 1 | | 35 | 346 | 346 | 126 | | |
| 84 | | 2 | | 35 | 46 | 346 | 346 | | |
| 85 | | 3 | | 346 | 35 | 124 | 46 | | |
| 86 | | | | | | | | | |
| 87 | | BRIGGS 1 | | 346 | 256 | 236 | 246 | | |
| 88 | | 2 | | 245 | 124 | 4 | 456 | | |
| 89 | | 3 | | 346 | 126 | 346 | 146 | | |
| 90 | | | | | | | | | |
| 91 | | HELLYAR 1 | | 15 | 13 | 146 | 25 | | |
| 92 | | 2 | | 15 | 26 | 156 | 235 | | |
| 93 | | 3 | | 15 | 15 | 146 | 235 | | |
| 94 | | | | | | | | | |
| 95 | | CAMPION 1 | | 34 | 24 | 13 | 1236 | | |
| 96 | | 2 | | 246 | 246 | 246 | 1246 | | |
| 97 | | 3 | | 246 | 24 | 246 | 12346 | | |
| 98 | | | | | | | | | |
| 99 | | BAGHOM 1 | | 124 | 12 | 1 | 3 | | |
| 100 | | 2 | | 145 | 2345 | 136 | 245 | | |
| 101 | | 3 | | 36 | 245 | 36 | 236 | | |
| 102 | | | | | | | | | |
| 103 | | HARRISON 1 | | 135 | 235 | 235 | 25 | | |
| 104 | | 2 | | 35 | 46 | 136 | 236 | | |
| 105 | | 3 | | 35 | 46 | 14 | 23 | | |
| 106 | | | | | | | | | |
| 107 | | VALLING 1 | | 125 | 245 | 126 | 35 | | |
| 108 | | 2 | | 245 | 125 | 1236 | 235 | | |
| 109 | | 3 | | 245 | 25 | 125 | 245 | | |
| 110 | | | | | | | | | |
| 111 | | FROST 1 | | 35 | 36 | 36 | 16 | | |
| 112 | | 2 | | 136 | 136 | 126 | 16 | | |
| 113 | | 3 | | 16 | 15 | 16 | 156 | | |
| 114 | | | | | | | | | |

# APPENDIX 9

SUBJECT PROTOCOLS : ONE AND TWO DOT BRAILLE CODES

| | |
|---|---|
| 1 | 2 |
| 3 | 4 |
| 5 | 6 |

| | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 |
|---|---|---|---|---|---|---|---|---|---|
| 115 | | | | | | | | | |
| 116 | | SUBJECT | | LV1 | LV2 | LD1 | LD2 | | |
| 117 | | | CODE | 15 | 26 | 16 | 25 | | |
| 118 | | | | | | | | | |
| 119 | | COOPER 1 | | 236 | 16 | 146 | 136 | | |
| 120 | | 2 | | 136 | 236 | 16 | 346 | | |
| 121 | | 3 | | 136 | 136 | 236 | 136 | | |
| 122 | | | | | | | | | |
| 123 | | | | | | | | | |
| 124 | | MARSH 1 | | 234 | 25 | 245 | 26 | | |
| 125 | | 2 | | 23 | 36 | 16 | 346 | | |
| 126 | | 3 | | 236 | 15 | 16 | 25 | | |
| 127 | | | | | | | | | |
| 128 | | NIX 1 | | 13 | 346 | 146 | 2345 | | |
| 129 | | 2 | | 35 | 46 | 346 | 1456 | | |
| 130 | | 3 | | 346 | 146 | 156 | 1346 | | |
| 131 | | | | | | | | | |
| 132 | | BOADLE 1 | | 456 | 36 | 36 | 26 | | |
| 133 | | 2 | | 26 | 26 | 26 | 26 | | |
| 134 | | 3 | | 26 | 16 | 16 | 16 | | |
| 135 | | | | | | | | | |
| 136 | | BOUZEID 1 | | 134 | 346 | 346 | 124 | | |
| 137 | | 2 | | 36 | 356 | 134 | 345 | | |
| 138 | | 3 | | 1246 | 124 | 1236 | 124 | | |
| 139 | | | | | | | | | |
| 140 | | JORQUE 1 | | 25 | 235 | 16 | 125 | | |
| 141 | | 2 | | 25 | 25 | 16 | 125 | | |
| 142 | | 3 | | 25 | 14 | 16 | 25 | | |
| 143 | | | | | | | | | |
| 144 | | DUNN 1 | | 346 | 346 | 36 | 5 | | |
| 145 | | 2 | | 24 | 35 | 2356 | 16 | | |
| 146 | | 3 | | 24 | 236 | 346 | 36 | | |
| 147 | | | | | | | | | |
| 148 | | SPORA 1 | | 34 | 56 | 346 | 23 | | |
| 149 | | 2 | | 15 | 26 | 26 | 26 | | |
| 150 | | 3 | | 3 | 24 | 236 | 126 | | |
| 151 | | | | | | | | | |
| 152 | | ZAGORSKI 1 | | 135 | 134 | 136 | 13 | | |
| 153 | | 2 | | 35 | 346 | 134 | 345 | | |
| 154 | | 3 | | 136 | 136 | 136 | 235 | | |
| 155 | | | | | | | | | |
| 156 | | NGUYEN 1 | | 13 | 246 | 24 | 23456 | | |
| 157 | | 2 | | 34 | 46 | 24 | 234 | | |
| 158 | | 3 | | 246 | 24 | 2 | 234 | | |
| 159 | | | | | | | | | |
| 160 | | GRIFFITHS 1 | | 135 | 35 | 345 | 145 | | |
| 161 | | 2 | | 35 | 234 | 134 | 235 | | |
| 162 | | 3 | | 13 | 34 | 134 | 2345 | | |
| 163 | | | | | | | | | |
| 164 | | LARKIN 1 | | 234 | 15 | 145 | 1356 | | |
| 165 | | 2 | | 145 | 35 | 145 | 25 | | |
| 166 | | 3 | | 145 | 123 | 145 | 1234 | | |
| 167 | | | | | | | | | |
| 168 | | MCCRAN 1 | | 46 | 24 | 24 | 234 | | |
| 169 | | 2 | | 56 | 13 | 45 | 13 | | |
| 170 | | | | | | | | | |
| 171 | | | | | | | | | |

## APPENDIX 9

| | |
|---|---|
| 1 | 2 |
| 3 | 4 |
| 5 | 6 |

SUBJECT PROTOCOLS : THREE DOT BRAILLE CODES

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| 1 | SUBJECT | CODE | | | | | | |
| 2 | | 123 | 124 | 125 | 126 | 134 | 135 | 136 |
| 3 | 2ND SERIES | | | | | | | |
| 4 | CODES | | | | | | | |
| 5 | | | | | | | | |
| 6 | MEDINA 1 | 345 | 146 | 235 | 124 | 1245 | 135 | 136 |
| 7 | 2 | 345 | 1235 | 135 | 125 | 1356 | 46 | 136 |
| 8 | 3 | 235 | 346 | 235 | 1235 | 1356 | 135 | 246 |
| 9 | | | | | | | | |
| 10 | JONES 1 | 123 | 1345 | 125 | 126 | 124 | 23 | 125 |
| 11 | 2 | 123 | 134 | 14 | 125 | 345 | 13 | 145 |
| 12 | 3 | 124 | 124 | 125 | 126 | 2356 | 14 | 124 |
| 13 | | | | | | | | |
| 14 | FALKINER 1 | 1235 | 123 | 1345 | 12346 | 12346 | 1246 | 134 |
| 15 | 2 | 1234 | 1234 | 1235 | 12346 | 124 | 246 | 1236 |
| 16 | 3 | 234 | 234 | 2346 | 124 | 1234 | 135 | 12346 |
| 17 | | | | | | | | |
| 18 | FROST 1 | 136 | 12346 | 12346 | 134 | 146 | 246 | 124 |
| 19 | 2 | 1246 | 146 | 1246 | 13456 | 1346 | 246 | 13456 |
| 20 | 3 | 12346 | 1246 | 12346 | 1345 | 12345 | 246 | 12346 |
| 21 | | | | | | | | |
| 22 | TAN 1 | 12346 | 124 | 136 | 145 | 1234 | 34 | 146 |
| 23 | 2 | 124 | 16 | 16 | 126 | 12 | 45 | 146 |
| 24 | 3 | 234 | 1346 | 245 | 1246 | 1245 | 24 | 146 |
| 25 | | | | | | | | |
| 26 | GRANT 1 | 123 | 1234 | 1345 | 1236 | 124 | 35 | 124 |
| 27 | 2 | 123 | 12 | 123 | 1346 | 123 | 0 | 346 |
| 28 | 3 | 123 | 1234 | 12 | 12346 | 1234 | 13 | 12346 |
| 29 | | | | | | | | |
| 30 | PEARSON 1 | 12 | 1234 | 123456 | 1246 | 1234 | 234 | 14 |
| 31 | 2 | 12 | 124 | 236 | 1246 | 2346 | 135 | 124 |
| 32 | 3 | 124 | 0 | 1345 | 236 | 346 | 135 | 346 |
| 33 | | | | | | | | |
| 34 | MOORE 1 | 1234 | 134 | 256 | 126 | 124 | 135 | 14 |
| 35 | 2 | 123 | 12 | 256 | 16 | 345 | 135 | 136 |
| 36 | 3 | 123 | 124 | 16 | 126 | 1246 | 135 | 124 |
| 37 | | | | | | | | |
| 38 | DEWAR 1 | 123 | 124 | 123 | 16 | 1236 | 456 | 346 |
| 39 | 2 | 1234 | 346 | 1256 | 136 | 123 | 346 | 1246 |
| 40 | 3 | 126 | 124 | 2346 | 1236 | 12346 | 35 | 1236 |
| 41 | | | | | | | | |
| 42 | WATMAN 1 | 12 | 1246 | 1246 | 1246 | 134 | 246 | 1356 |
| 43 | 2 | 123 | 123 | 12356 | 1246 | 134 | 246 | 1356 |
| 44 | 3 | 124 | 1246 | 1246 | 126 | 124 | 135 | 135 |
| 45 | | | | | | | | |
| 46 | STRAIN 1 | 456 | 346 | 23456 | 126 | 1356 | 12456 | 346 |
| 47 | 2 | 1234 | 23456 | 123456 | 1246 | 1234 | 346 | 2456 |
| 48 | 3 | 12 | 346 | 3456 | 1245 | 134 | 234 | 345 |
| 49 | | | | | | | | |
| 50 | FABIAN 1 | 12 | 36 | 145 | 136 | 134 | 345 | 136 |
| 51 | 2 | 34 | 1356 | 1345 | 146 | 0 | 135 | 156 |
| 52 | 3 | 24 | 35 | 145 | 156 | 123 | 135 | 136 |
| 53 | | | | | | | | |
| 54 | | | | | | | | |
| 55 | | | | | | | | |
| 56 | | | | | | | | |
| 57 | | | | | | | | |

# APPENDIX 9

| | |
|---|---|
| 1 | 2 |
| 3 | 4 |
| 5 | 6 |

SUBJECT PROTOCOLS : THREE DOT BRAILLE CODES

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| 58 | | | | | | | | |
| 59 | | CODE | | | | | | |
| 60 | | 123 | 124 | 125 | 126 | 134 | 135 | 136 |
| 61 | | | | | | | | |
| 62 | SHARP 1 | 12 | 356 | 356 | 1246 | 124 | 135 | 235 |
| 63 | 2 | 23 | 245 | 345 | 1245 | 234 | 246 | 2345 |
| 64 | 3 | 124 | 124 | 245 | 345 | 456 | 456 | 235 |
| 65 | | | | | | | | |
| 66 | PERIC 1 | 234 | 234 | 2345 | 346 | 346 | 35 | 346 |
| 67 | 2 | 346 | 346 | 2345 | 136 | 2346 | 35 | 134 |
| 68 | 3 | 23 | 234 | 235 | 126 | 23 | 13 | 234 |
| 69 | | | | | | | | |
| 70 | BERNOTAS 1 | 56 | 56 | 34 | 246 | 12 | 135 | 35 |
| 71 | 2 | 34 | 345 | 345 | 12345 | 12 | 135 | 12 |
| 72 | 3 | 346 | 235 | 3456 | 126 | 1245 | 3456 | 246 |
| 73 | | | | | | | | |
| 74 | TURNER 1 | 12 | 346 | 15 | 12346 | 1234 | 46 | 36 |
| 75 | 2 | 34 | 124 | 346 | 126 | 1234 | 46 | 26 |
| 76 | 3 | 124 | 1234 | 1235 | 1246 | 124 | 35 | 1236 |
| 77 | | | | | | | | |
| 78 | 1st SERIES | | | | | | | |
| 79 | CODES | | | | | | | |
| 80 | | | | | | | | |
| 81 | MOLLISON 1 | 23456 | 12346 | 3456 | 346 | 34 | 246 | 356 |
| 82 | 2 | 346 | 346 | 346 | 346 | .56 | 3456 | 345 |
| 83 | 3 | 346 | 346 | 356 | 346 | 346 | 246 | 456 |
| 84 | | | | | | | | |
| 85 | BRIGGS 1 | 124 | 234 | 26 | 2356 | 356 | 245 | 146 |
| 86 | 2 | 45 | 1246 | 346 | 1246 | 456 | 24 | 346 |
| 87 | 3 | 456 | 3456 | 1456 | 1456 | 46 | 46 | 3456 |
| 88 | | | | | | | | |
| 89 | HELLYAR 1 | 124 | 124 | 134 | 123 | 1346 | 2345 | 124 |
| 90 | 2 | 345 | 124 | 135 | 1236 | 134 | 245 | 136 |
| 91 | 3 | 123 | 3456 | 1246 | 1236 | 1346 | 234 | 136 |
| 92 | | | | | | | | |
| 93 | CAMPION 1 | 345 | 34 | 12346 | 1236 | 12346 | 3456 | 3 |
| 94 | 2 | 1246 | 26 | 146 | 134 | 1346 | 124 | 1346 |
| 95 | 3 | 12346 | 246 | 12346 | 12346 | 1246 | 246 | 246 |
| 96 | | | | | | | | |
| 97 | BAGHOM 1 | 12 | 1234 | 3 | 146 | 234 | 124 | 124 |
| 98 | 2 | 1234 | 346 | 245 | 126 | 34 | 246 | 14 |
| 99 | 3 | 12 | 124 | 26 | 235 | 123 | 246 | 126 |
| 100 | | | | | | | | |
| 101 | HARRISON 1 | 123 | 14 | 1345 | 1245 | 124 | 135 | 14 |
| 102 | 2 | 234 | 236 | 123 | 1246 | 124 | 246 | 1236 |
| 103 | 3 | 1235 | 124 | 14 | 12346 | 14 | 1235 | 1356 |
| 104 | | | | | | | | |
| 105 | VALLING 1 | 124 | 124 | 125 | 1246 | 24 | 356 | 1246 |
| 106 | 2 | 123 | 1456 | 345 | 1235 | 1234 | 123 | 236 |
| 107 | 3 | 124 | 236 | 245 | 125 | 134 | 345 | 2346 |
| 108 | | | | | | | | |
| 109 | FROST 1 | 12 | 356 | 14 | 146 | 134 | 1246 | 356 |
| 110 | 2 | 124 | 134 | 124 | 1246 | 124 | 46 | 46 |
| 111 | 3 | 124 | 124 | 1246 | 1246 | 34 | 35 | 1234 |
| 112 | | | | | | | | |
| 113 | | | | | | | | |
| 114 | | | | | | | | |

# APPENDIX 9

| | |
|---|---|
| 1 | 2 |
| 3 | 4 |
| 5 | 6 |

SUBJECT PROTOCOLS : THREE DOT BRAILLE CODES

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| 115 | | | | | | | | |
| 116 | | | | | | | | |
| 117 | SUBJECT | CODE | | | | | | |
| 118 | | 123 | 124 | 125 | 126 | 134 | 135 | 136 |
| 119 | | | | | | | | |
| 120 | | | | | | | | |
| 121 | COOPER 1 | 123 | 134 | 136 | 126 | 123 | 146 | 126 |
| 122 | 2 | 134 | 346 | 136 | 136 | 34 | 2346 | 124 |
| 123 | 3 | 346 | 346 | 136 | 136 | 345 | 35 | 1236 |
| 124 | | | | | | | | |
| 125 | MARSH 1 | 23 | 234 | 236 | 1236 | 245 | 246 | 234 |
| 126 | 2 | 1234 | 1346 | 136 | 146 | 124 | 345 | 234 |
| 127 | 3 | 234 | 356 | 256 | 2346 | 2346 | 346 | 25 |
| 128 | | | | | | | | |
| 129 | | | | | | | | |
| 130 | NIX 1 | 234 | 356 | 234 | 456 | 12 | 2346 | 1234 |
| 131 | 2 | 34 | 124 | 2356 | 1456 | 345 | 2346 | 146 |
| 132 | 3 | 124 | 236 | 135 | 126 | 124 | 24 | 124 |
| 133 | | | | | | | | |
| 134 | BOADLE 1 | 1234 | 346 | 2346 | 126 | 24 | 1234 | 12346 |
| 135 | 2 | 12 | 124 | 46 | 26 | 2346 | 134 | 346 |
| 136 | 3 | 12 | 124 | 26 | 346 | 124 | 124 | 346 |
| 137 | | | | | | | | |
| 138 | BOUZEID 1 | 24 | 1234 | 124 | 134 | 34 | 1234 | 134 |
| 139 | 2 | 12 | 134 | 14 | 124 | 12 | 346 | 1234 |
| 140 | 3 | 12 | 12 | 124 | 124 | 34 | 24 | 124 |
| 141 | | | | | | | | |
| 142 | JORQUE 1 | 1235 | 345 | 1245 | 12346 | 1236 | 246 | 126 |
| 143 | 2 | 1345 | 14 | 1245 | 126 | 1246 | 135 | 13 |
| 144 | 3 | 12 | 123 | 1235 | 126 | 1246 | 135 | 126 |
| 145 | | | | | | | | |
| 146 | DUNN 1 | 346 | 346 | 46 | 126 | 34 | 124 | 346 |
| 147 | 2 | 35 | 346 | 13 | 1256 | 34 | 34 | 346 |
| 148 | 3 | 234 | 3456 | 4 | 14 | 234 | 34 | 256 |
| 149 | | | | | | | | |
| 150 | SPORA 1 | 46 | 234 | 124 | 236 | 14 | 2 | 234 |
| 151 | 2 | 345 | 234 | 124 | 346 | 245 | 235 | 36 |
| 152 | 3 | 12 | 1345 | 1246 | 236 | 136 | 26 | 14 |
| 153 | | | | | | | | |
| 154 | ZAGORSKI 1 | 34 | 346 | 346 | 146 | 346 | 46 | 346 |
| 155 | 2 | 134 | 134 | 346 | 124 | 34 | 346 | 146 |
| 156 | 3 | 45 | 36 | 1234 | 136 | 34 | 13 | 346 |
| 157 | | | | | | | | |
| 158 | NGUYEN 1 | 12 | 1234 | 4 | 1246 | 234 | 24 | 246 |
| 159 | 2 | 34 | 2456 | 124 | 1246 | 34 | 246 | 24 |
| 160 | 3 | 2 | 234 | 1234 | 23 | 234 | 23 | 24 |
| 161 | | | | | | | | |
| 162 | GRIFFITHS 1 | 1234 | 345 | 34 | 124 | 346 | 34 | 134 |
| 163 | 2 | 124 | 34 | 3456 | 146 | 346 | 134 | 134 |
| 164 | 3 | 123 | 12 | 134 | 124 | 346 | 13 | 124 |
| 165 | | | | | | | | |
| 166 | LARKIN 1 | 234 | 34 | 145 | 1245 | 34 | 14 | 345 |
| 167 | 2 | 234 | 234 | 23 | 145 | 234 | 13 | 1234 |
| 168 | 3 | 134 | 1234 | 234 | 1234 | 3456 | 1234 | 134 |
| 169 | | | | | | | | |
| 170 | MCCRAN 1 | 456 | 12 | 124 | 124 | 124 | 3456 | 456 |
| 171 | 2 | 13 | 13 | 1 | 234 | 2 | 3 | 12 |

# APPENDIX 9

| | |
|---|---|
| 1 | 2 |
| 3 | 4 |
| 5 | 6 |

SUBJECT PROTOCOLS : THREE DOT BRAILLE CODES

| | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | SUBJECT | CODE | | | | | | | | | |
| 2 | | 145 | 146 | 156 | 234 | 235 | 236 | 245 | 246 | 256 | |
| 3 | 2ND SERIES | | | | | | | | | | |
| 4 | CODES | | | | | | | | | | |
| 5 | | | | | | | | | | | |
| 6 | MEDINA 1 | 3456 | 146 | 356 | 2346 | 235 | 2345 | 235 | 135 | 256 | |
| 7 | 2 | 3456 | 146 | 345 | 345 | 235 | 235 | 245 | 135 | 256 | |
| 8 | 3 | 12346 | 146 | 235 | 2345 | 135 | 2345 | 235 | 135 | 245 | |
| 9 | | | | | | | | | | | |
| 10 | JONES 1 | 124 | 146 | 45 | 124 | 135 | 1345 | 125 | 13 | 234 | |
| 11 | 2 | 134 | 1245 | 245 | 23 | 14 | 145 | 23 | 13 | 126 | |
| 12 | 3 | 1246 | 146 | 15 | 123 | 123 | 1245 | 145 | 15 | 2346 | |
| 13 | | | | | | | | | | | |
| 14 | FALKINER 1 | 12346 | 1356 | 12356 | 13456 | 1345 | 12345 | 2345 | 135 | 1345 | |
| 15 | 2 | 12346 | 2346 | 2356 | 134 | 236 | 12345 | 12345 | 123 | 12456 | |
| 16 | 3 | 12346 | 234 | 1245 | 23 | 12345 | 256 | 2346 | 134 | 234 | |
| 17 | | | | | | | | | | | |
| 18 | FROST 1 | 12346 | 126 | 1346 | 1346 | 135 | 12346 | 1246 | 246 | 146 | |
| 19 | 2 | 13456 | 136 | 245 | 1346 | 136 | 1246 | 146 | 246 | 136 | |
| 20 | 3 | 12346 | 136 | 1345 | 12346 | 135 | 1346 | 1346 | 246 | 1456 | |
| 21 | | | | | | | | | | | |
| 22 | TAN 1 | 12345 | 146 | 1356 | 346 | 123 | 136 | 245 | 126 | 245 | |
| 23 | 2 | 1245 | 146 | 235 | 124 | 35 | 145 | 245 | 146 | 234 | |
| 24 | 3 | 12346 | 146 | 156 | 23 | 235 | 136 | 245 | 16 | 2345 | |
| 25 | | | | | | | | | | | |
| 26 | GRANT 1 | 1234 | 1236 | 13456 | 123 | 123 | 1235 | 135 | 12345 | 456 | |
| 27 | 2 | 1234 | 136 | 356 | 1245 | 123 | 123 | 234 | 13 | 2346 | |
| 28 | 3 | 12345 | 1236 | 345 | 345 | 245 | 2345 | 2345 | 1234 | 1234 | |
| 29 | | | | | | | | | | | |
| 30 | PEARSON 1 | 1234 | 124 | 135 | 134 | 13 | 13456 | 134 | 13 | 234 | |
| 31 | 2 | 1234 | 124 | 236 | 346 | 234 | 346 | 234 | 13 | 145 | |
| 32 | 3 | 2346 | 13 | 136 | 23 | 245 | 145 | 456 | 46 | 2346 | |
| 33 | | | | | | | | | | | |
| 34 | MOORE 1 | 124 | 146 | 156 | 2346 | 2345 | 346 | 1245 | 1345 | 256 | |
| 35 | 2 | 136 | 146 | 156 | 234 | 2456 | 126 | 245 | 135 | 2356 | |
| 36 | 3 | 1346 | 146 | 156 | 34 | 2356 | 2356 | 235 | 35 | 125 | |
| 37 | | | | | | | | | | | |
| 38 | DEWAR 1 | 3456 | 2346 | 125 | 346 | 2456 | 1246 | 124 | 124 | 346 | |
| 39 | 2 | 12346 | 346 | 2356 | 2456 | 456 | 346 | 346 | 234 | 256 | |
| 40 | 3 | 1236 | 136 | 256 | 1234 | 345 | 126 | 236 | 12346 | 146 | |
| 41 | | | | | | | | | | | |
| 42 | WATMAN 1 | 1346 | 1246 | 156 | 234 | 135 | 1356 | 12456 | 13 | 1256 | |
| 43 | 2 | 12456 | 126 | 156 | 456 | 1235 | 12356 | 2456 | 35 | 256 | |
| 44 | 3 | 12345 | 124 | 156 | 234 | 235 | 12356 | 2456 | 135 | 2456 | |
| 45 | | | | | | | | | | | |
| 46 | STRAIN 1 | 234 | 124 | 135 | 2456 | 356 | 13 | 456 | 46 | 23456 | |
| 47 | 2 | 124 | 126 | 356 | 234 | 246 | 23456 | 23456 | 3456 | 2456 | |
| 48 | 3 | 123 | 124 | 356 | 13 | 456 | 3456 | 345 | 346 | 235 | |
| 49 | | | | | | | | | | | |
| 50 | FABIAN 1 | 12456 | 356 | 356 | 235 | 135 | 3456 | 135 | 13 | 345 | |
| 51 | 2 | 2345 | 145 | 145 | 134 | 235 | 236 | 2345 | 135 | 1456 | |
| 52 | 3 | 1456 | 145 | 145 | 13 | 25 | 245 | 245 | 135 | 234 | |
| 53 | | | | | | | | | | | |
| 54 | | | | | | | | | | | |
| 55 | | | | | | | | | | | |
| 56 | | | | | | | | | | | |
| 57 | | | | | | | | | | | |

# APPENDIX 9

| | |
|---|---|
| 1 | 2 |
| 3 | 4 |
| 5 | 6 |

SUBJECT PROTOCOLS : THREE DOT BRAILLE CODES

| | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 58 | | | | | | | | | | | |
| 59 | SUBJECT | CODE | | | | | | | | | |
| 60 | | 145 | 146 | 156 | 234 | 235 | 236 | 245 | 246 | 256 | |
| 61 | | | | | | | | | | | |
| 62 | SHARP 1 | 123456 | 346 | 346 | 56 | 456 | 134 | 3456 | 34 | 245 | |
| 63 | 2 | 12345 | 456 | 245 | 123 | 345 | 346 | 456 | 345 | 2345 | |
| 64 | 3 | 456 | 2346 | 2456 | 12 | 245 | 2346 | 2456 | 24 | 256 | |
| 65 | | | | | | | | | | | |
| 66 | PERIC 1 | 3456 | 346 | 136 | 235 | 134 | 234 | 234 | 24 | 345 | |
| 67 | 2 | 2345 | 345 | 346 | 234 | 234 | 2346 | 234 | 13 | 2345 | |
| 68 | 3 | 234 | 23 | 236 | 234 | 2345 | 2346 | 235 | 35 | 236 | |
| 69 | | | | | | | | | | | |
| 70 | BERNOTAS 1 | 13456 | 345 | 356 | 2345 | 23456 | 234 | 345 | 34 | 345 | |
| 71 | 2 | 2345 | 1345 | 135 | 456 | 234 | 235 | 1234 | 135 | 12345 | |
| 72 | 3 | 2345 | 3456 | 2345 | 12 | 2345 | 2345 | 2345 | 345 | 3456 | |
| 73 | | | | | | | | | | | |
| 74 | TURNER 1 | 3456 | 1246 | 36 | 24 | 12345 | 456 | 345 | 246 | 15 | |
| 75 | 2 | 234 | 14 | 13 | 46 | 1345 | 346 | 346 | 46 | 3456 | |
| 76 | 3 | 12346 | 126 | 126 | 34 | 236 | 124 | 123 | 13 | 234 | |
| 77 | | | | | | | | | | | |
| 78 | 1st SERIES | | | | | | | | | | |
| 79 | CODES | | | | | | | | | | |
| 80 | | | | | | | | | | | |
| 81 | MOLLISON 1 | 346 | 346 | 346 | 346 | 146 | 346 | 3456 | 3456 | 345 | |
| 82 | 2 | 1346 | 246 | 356 | 456 | 1356 | 346 | 34 | 35 | 356 | |
| 83 | 3 | 346 | 356 | 3456 | 345 | 356 | 346 | 456 | 46 | 56 | |
| 84 | | | | | | | | | | | |
| 85 | BRIGGS 1 | 2346 | 3456 | 2346 | 346 | 2346 | 2346 | 346 | 246 | 2346 | |
| 86 | 2 | 124 | 3456 | 246 | 1245 | 146 | 346 | 2346 | 246 | 2456 | |
| 87 | 3 | 236 | 146 | 456 | 234 | 2456 | 2456 | 146 | 246 | 2346 | |
| 88 | | | | | | | | | | | |
| 89 | HELLYAR 1 | 13456 | 146 | 1346 | 2345 | 2356 | 2356 | 2345 | 234 | 156 | |
| 90 | 2 | 136 | 126 | 2356 | 2346 | 1245 | 12345 | 2345 | 246 | 156 | |
| 91 | 3 | 13456 | 146 | 1456 | 1346 | 2345 | 2346 | 2456 | 12346 | 256 | |
| 92 | | | | | | | | | | | |
| 93 | CAMPION 1 | 246 | 1246 | 134 | 3456 | 34 | 1234 | 35 | 246 | 124 | |
| 94 | 2 | 1246 | 1246 | 246 | 1234 | 1234 | 1346 | 146 | 1234 | 1246 | |
| 95 | 3 | 1346 | 2 | 246 | 246 | 246 | 1246 | 246 | 246 | 1246 | |
| 96 | | | | | | | | | | | |
| 97 | BAGHOM 1 | 2456 | 14 | 126 | 1246 | 2345 | 2346 | 24 | 12 | 126 | |
| 98 | 2 | 136 | 146 | 256 | 234 | 234 | 1235 | 245 | 245 | 456 | |
| 99 | 3 | 12456 | 146 | 256 | 346 | 235 | 346 | 346 | 35 | 456 | |
| 100 | | | | | | | | | | | |
| 101 | HARRISON 1 | 1346 | 14 | 1235 | 235 | 235 | 124 | 345 | 24 | 45 | |
| 102 | 2 | 23456 | 146 | 136 | 345 | 2346 | 2345 | 235 | 135 | 245 | |
| 103 | 3 | 1456 | 1345 | 236 | 234 | 234 | 234 | 256 | 135 | 146 | |
| 104 | | | | | | | | | | | |
| 105 | VALLING 1 | 12456 | 12456 | 125 | 456 | 2345 | 1245 | 245 | 24 | 1245 | |
| 106 | 2 | 236 | 1234 | 136 | 2346 | 1236 | 2356 | 245 | 2345 | 12456 | |
| 107 | 3 | 124 | 146 | 156 | 236 | 2456 | 236 | 2356 | 134 | 1245 | |
| 108 | | | | | | | | | | | |
| 109 | FROST 1 | 1234 | 146 | 1234 | 1246 | 1346 | 1246 | 36 | 146 | 124 | |
| 110 | 2 | 1245 | 146 | 1246 | 1346 | 1345 | 1246 | 26 | 24 | 124 | |
| 111 | 3 | 1246 | 12346 | 136 | 124 | 124 | 1234 | 15 | 124 | 134 | |
| 112 | | | | | | | | | | | |
| 113 | | | | | | | | | | | |
| 114 | | | | | | | | | | | |

| | |
|---|---|
| 1 | 2 |
| 3 | 4 |
| 5 | 6 |

# APPENDIX 9

SUBJECT PROTOCOLS : THREE DOT BRAILLE CODES

| | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 115 | | | | | | | | | | | |
| 116 | | | | | | | | | | | |
| 117 | SUBJECT | CODE | | | | | | | | | |
| 118 | | 145 | 146 | 156 | 234 | 235 | 236 | 245 | 246 | 256 | |
| 119 | | | | | | | | | | | |
| 120 | | | | | | | | | | | |
| 121 | COOPER 1 | 136 | 146 | 356 | 345 | 245 | 124 | 345 | 124 | 235 | |
| 122 | 2 | 1236 | 346 | 146 | 234 | 136 | 1346 | 36 | 13 | 36 | |
| 123 | 3 | 236 | 124 | 136 | 234 | 2345 | 1356 | 456 | 146 | 235 | |
| 124 | | | | | | | | | | | |
| 125 | MARSH 1 | 12346 | 1246 | 245 | 345 | 3456 | 1236 | 245 | 1246 | 245 | |
| 126 | 2 | 134 | 346 | 245 | 234 | 26 | 2346 | 456 | 146 | 235 | |
| 127 | 3 | 236 | 1246 | 2346 | 245 | 2456 | 346 | 2345 | 246 | 346 | |
| 128 | | | | | | | | | | | |
| 129 | | | | | | | | | | | |
| 130 | NIX 1 | 23456 | 346 | 346 | 34 | 356 | 12345 | 345 | 46 | 346 | |
| 131 | 2 | 56 | 346 | 356 | 234 | 2346 | 12456 | 2456 | 236 | 35 | |
| 132 | 3 | 134 | 146 | 3456 | 456 | 34 | 136 | 256 | 135 | 245 | |
| 133 | | | | | | | | | | | |
| 134 | BOADLE 1 | 23456 | 124 | 346 | 1234 | 246 | 23456 | 3456 | 2346 | 456 | |
| 135 | 2 | 34 | 46 | 236 | 24 | 256 | 46 | 256 | 2456 | 246 | |
| 136 | 3 | 146 | 234 | 246 | 124 | 46 | 346 | 346 | 24 | 246 | |
| 137 | | | | | | | | | | | |
| 138 | BOUZEID 1 | 234 | 356 | 356 | 3456 | 234 | 1234 | 4 | 35 | 456 | |
| 139 | 2 | 456 | 124 | 134 | 12 | 13456 | 34 | 356 | 1234 | 356 | |
| 140 | 3 | 346 | 124 | 146 | 34 | 345 | 1234 | 124 | 24 | 1234 | |
| 141 | | | | | | | | | | | |
| 142 | JORQUE 1 | 12345 | 126 | 156 | 2345 | 2345 | 1245 | 245 | 136 | 256 | |
| 143 | 2 | 1456 | 1246 | 156 | 456 | 1235 | 1456 | 2456 | 135 | 245 | |
| 144 | 3 | 1356 | 146 | 1345 | 1245 | 235 | 1245 | 245 | 135 | 145 | |
| 145 | | | | | | | | | | | |
| 146 | DUNN 1 | 2346 | 246 | 346 | 34 | 23456 | 12346 | 236 | 24 | 34 | |
| 147 | 2 | 2346 | 236 | 356 | 234 | 46 | 234 | 234 | 346 | 2346 | |
| 148 | 3 | 234 | 2346 | 2346 | 34 | 36 | 345 | 235 | 12 | 236 | |
| 149 | | | | | | | | | | | |
| 150 | SPORA 1 | 46 | 346 | 126 | 234 | 134 | 2346 | 345 | 34 | 346 | |
| 151 | 2 | 345 | 14 | 24 | 2346 | 124 | 236 | 15 | 34 | 256 | |
| 152 | 3 | 1345 | 126 | 26 | 45 | 134 | 146 | 456 | 12 | 345 | |
| 153 | | | | | | | | | | | |
| 154 | ZAGORSKI 1 | 123 | 134 | 3456 | 345 | 345 | 356 | 356 | 13 | 2456 | |
| 155 | 2 | 1356 | 1346 | 346 | 345 | 345 | 245 | 45 | 13 | 345 | |
| 156 | 3 | 234 | 1346 | 136 | 346 | 235 | 1346 | 245 | 134 | 345 | |
| 157 | | | | | | | | | | | |
| 158 | NGUYEN 1 | 23456 | 246 | 246 | 1234 | 3456 | 246 | 234 | 24 | 2346 | |
| 159 | 2 | 24 | 1234 | 3456 | 234 | 234 | 2456 | 234 | 24 | 23456 | |
| 160 | 3 | 23456 | 234 | 346 | 34 | 234 | 234 | 234 | 24 | 23456 | |
| 161 | | | | | | | | | | | |
| 162 | GRIFFITHS 1 | 456 | 346 | 236 | 3456 | 346 | 3456 | 12345 | 346 | 23456 | |
| 163 | 2 | 13456 | 124 | 1345 | 45 | 2345 | 23456 | 3456 | 1234 | 134 | |
| 164 | 3 | 135 | 23456 | 456 | 1234 | 2345 | 12346 | 3456 | 3456 | 345 | |
| 165 | | | | | | | | | | | |
| 166 | LARKIN 1 | 1456 | 1234 | 134 | 23 | 234 | 12345 | 234 | 234 | 2346 | |
| 167 | 2 | 2346 | 12346 | 135 | 34 | 345 | 1456 | 134 | 1234 | 136 | |
| 168 | 3 | 3456 | 123 | 256 | 1234 | 13456 | 1234 | 1345 | 12 | 234 | |
| 169 | | | | | | | | | | | |
| 170 | MCCRAN 1 | 124 | 1246 | 12 | 124 | 1234 | 23456 | 35 | 246 | 35 | |
| 171 | 2 | 2 | 124 | 3456 | 13 | 35 | 124 | 35 | 24 | 345 | |

# APPENDIX 9

| | |
|---|---|
| 1 | 2 |
| 3 | 4 |
| 5 | 6 |

SUBJECT PROTOCOLS : THREE DOT BRAILLE CODES

| | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 |
|---|---|---|---|---|---|---|---|---|---|
| 1 | SUBJECT | CODE | | | | | | | |
| 2 | | 345 | 346 | 356 | 456 | | | | |
| 3 | 2ND SERIES | | | | | | | | |
| 4 | CODES | | | | | | | | |
| 5 | | | | | | | | | |
| 6 | MEDINA 1 | 345 | 123 | 34 | 235 | | | | |
| 7 | 2 | 235 | 3456 | 345 | 2456 | | | | |
| 8 | 3 | 2345 | 3456 | 345 | 2356 | | | | |
| 9 | | | | | | | | | |
| 10 | JONES 1 | 123 | 35 | 346 | 134 | | | | |
| 11 | 2 | 14 | 346 | 24 | 34 | | | | |
| 12 | 3 | 245 | 1245 | 25 | 234 | | | | |
| 13 | | | | | | | | | |
| 14 | FALKINER 1 | 1346 | 1345 | 346 | 134 | | | | |
| 15 | 2 | 123 | 1234 | 1345 | 1345 | | | | |
| 16 | 3 | 2356 | 234 | 2346 | 12345 | | | | |
| 17 | | | | | | | | | |
| 18 | FROST 1 | 123456 | 146 | 35 | 2346 | | | | |
| 19 | 2 | 2346 | 1346 | 346 | 345 | | | | |
| 20 | 3 | 1346 | 1346 | 1345 | 13456 | | | | |
| 21 | | | | | | | | | |
| 22 | TAN 1 | 234 | 134 | 134 | 134 | | | | |
| 23 | 2 | 234 | 12 | 3456 | 245 | | | | |
| 24 | 3 | 345 | 2346 | 345 | 345 | | | | |
| 25 | | | | | | | | | |
| 26 | GRANT 1 | 1345 | 3456 | 234 | 356 | | | | |
| 27 | 2 | 345 | 346 | 146 | 34 | | | | |
| 28 | 3 | 3456 | 346 | 356 | 345 | | | | |
| 29 | | | | | | | | | |
| 30 | PEARSON 1 | 34 | 124 | 34 | 234 | | | | |
| 31 | 2 | 1234 | 124 | 346 | 346 | | | | |
| 32 | 3 | 3456 | 3456 | 3456 | 3456 | | | | |
| 33 | | | | | | | | | |
| 34 | MOORE 1 | 345 | 346 | 3456 | 345 | | | | |
| 35 | 2 | 345 | 146 | 356 | 346 | | | | |
| 36 | 3 | 345 | 356 | 346 | 345 | | | | |
| 37 | | | | | | | | | |
| 38 | DEWAR 1 | 346 | 346 | 346 | 2346 | | | | |
| 39 | 2 | 124 | 346 | 356 | 346 | | | | |
| 40 | 3 | 126 | 3456 | 134 | 126 | | | | |
| 41 | | | | | | | | | |
| 42 | WATMAN 1 | 2346 | 1246 | 345 | 346 | | | | |
| 43 | 2 | 345 | 456 | 456 | 456 | | | | |
| 44 | 3 | 1234 | 1356 | 456 | 456 | | | | |
| 45 | | | | | | | | | |
| 46 | STRAIN 1 | 346 | 34 | 456 | 3456 | | | | |
| 47 | 2 | 3456 | 13 | 346 | 456 | | | | |
| 48 | 3 | 34 | 345 | 35 | 56 | | | | |
| 49 | | | | | | | | | |
| 50 | FABIAN 1 | 56 | 1346 | 345 | 45 | | | | |
| 51 | 2 | 345 | 1246 | 356 | 456 | | | | |
| 52 | 3 | 145 | 346 | 3456 | 345 | | | | |
| 53 | | | | | | | | | |
| 54 | | | | | | | | | |
| 55 | | | | | | | | | |
| 56 | | | | | | | | | |
| 57 | | | | | | | | | |

| | |
|---|---|
| 1 | 2 |
| 3 | 4 |
| 5 | 6 |

# APPENDIX 9

SUBJECT PROTOCOLS : THREE DOT BRAILLE CODES

| | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 |
|---|---|---|---|---|---|---|---|---|---|
| 58 | | | | | | | | | |
| 59 | SUBJECT | CODE | | | | | | | |
| 60 | | 345 | 346 | 356 | 456 | | | | |
| 61 | | | | | | | | | |
| 62 | SHARP 1 | 346 | 346 | 45 | 234 | | | | |
| 63 | 2 | 34 | 345 | 34 | 234 | | | | |
| 64 | 3 | 34 | 346 | 34 | 34 | | | | |
| 65 | | | | | | | | | |
| 66 | PERIC 1 | 234 | 346 | 456 | 234 | | | | |
| 67 | 2 | 346 | 346 | 234 | 234 | | | | |
| 68 | 3 | 234 | 234 | 346 | 235 | | | | |
| 69 | | | | | | | | | |
| 70 | BERNOTAS 1 | 456 | 34 | 345 | 36 | | | | |
| 71 | 2 | 356 | 345 | 234 | 1234 | | | | |
| 72 | 3 | 245 | 345 | 345 | 245 | | | | |
| 73 | | | | | | | | | |
| 74 | TURNER 1 | 345 | 56 | 6 | 345 | | | | |
| 75 | 2 | 346 | 135 | 56 | 456 | | | | |
| 76 | 3 | 123 | 134 | 36 | 34 | | | | |
| 77 | | | | | | | | | |
| 78 | 1st SERIES | | | | | | | | |
| 79 | CODES | | | | | | | | |
| 80 | | | | | | | | | |
| 81 | MOLLISON 1 | 12346 | 346 | 3456 | 3456 | | | | |
| 82 | 2 | 356 | 3456 | 3456 | 23456 | | | | |
| 83 | 3 | 3456 | 356 | 2346 | 13456 | | | | |
| 84 | | | | | | | | | |
| 85 | BRIGGS 1 | 2346 | 456 | 234 | 456 | | | | |
| 86 | 2 | 2346 | 346 | 356 | 245 | | | | |
| 87 | 3 | 234 | 456 | 34 | 456 | | | | |
| 88 | | | | | | | | | |
| 89 | HELLYAR 1 | 1346 | 1234 | 1345 | 12345 | | | | |
| 90 | 2 | 345 | 345 | 346 | 1456 | | | | |
| 91 | 3 | 34 | 134 | 345 | 345 | | | | |
| 92 | | | | | | | | | |
| 93 | CAMPION 1 | 3456 | 13456 | 5 | 56 | | | | |
| 94 | 2 | 34 | 3456 | 1346 | 34 | | | | |
| 95 | 3 | 1246 | 1246 | 34 | 34 | | | | |
| 96 | | | | | | | | | |
| 97 | BAGHOM 1 | 34 | 34 | 34 | 34 | | | | |
| 98 | 2 | 346 | 146 | 346 | 1346 | | | | |
| 99 | 3 | 346 | 124 | 1346 | 456 | | | | |
| 100 | | | | | | | | | |
| 101 | HARRISON 1 | 12346 | 14 | 145 | 345 | | | | |
| 102 | 2 | 235 | 136 | 24 | 2345 | | | | |
| 103 | 3 | 1235 | 1345 | 1346 | 1345 | | | | |
| 104 | | | | | | | | | |
| 105 | VALLING 1 | 123456 | 1246 | 456 | 3456 | | | | |
| 106 | 2 | 234 | 124 | 356 | 1236 | | | | |
| 107 | 3 | 3456 | 2346 | 346 | 346 | | | | |
| 108 | | | | | | | | | |
| 109 | FROST 1 | 124 | 1245 | 346 | 56 | | | | |
| 110 | 2 | 35 | 36 | 356 | 356 | | | | |
| 111 | 3 | 34 | 1246 | 346 | 346 | | | | |
| 112 | | | | | | | | | |
| 113 | | | | | | | | | |
| 114 | | | | | | | | | |

# APPENDIX 9

| 1 | 2 |
|---|---|
| 3 | 4 |
| 5 | 6 |

SUBJECT PROTOCOLS : THREE DOT BRAILLE CODES

| | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 |
|---|---|---|---|---|---|---|---|---|---|
| 115 | | | | | | | | | |
| 116 | | | | | | | | | |
| 117 | SUBJECT | CODE | | | | | | | |
| 118 | | 345 | 346 | 356 | 456 | | | | |
| 119 | | | | | | | | | |
| 120 | | | | | | | | | |
| 121 | COOPER 1 | 234 | 2346 | 34 | 345 | | | | |
| 122 | 2 | 34 | 345 | 234 | 2346 | | | | |
| 123 | 3 | 34 | 346 | 345 | 345 | | | | |
| 124 | | | | | | | | | |
| 125 | MARSH 1 | 346 | 2346 | 3456 | 146 | | | | |
| 126 | 2 | 234 | 124 | 3456 | 356 | | | | |
| 127 | 3 | 3456 | 346 | 346 | 2456 | | | | |
| 128 | | | | | | | | | |
| 129 | | | | | | | | | |
| 130 | NIX 1 | 34 | 346 | 346 | 345 | | | | |
| 131 | 2 | 2345 | 1346 | 345 | 345 | | | | |
| 132 | 3 | 1346 | 346 | 346 | 346 | | | | |
| 133 | | | | | | | | | |
| 134 | BOADLE 1 | 3456 | 346 | 1246 | 124 | | | | |
| 135 | 2 | 46 | 346 | 56 | 456 | | | | |
| 136 | 3 | 46 | 2456 | 46 | 456 | | | | |
| 137 | | | | | | | | | |
| 138 | BOUZEID 1 | 346 | 3456 | 134 | 345 | | | | |
| 139 | 2 | 1234 | 124 | 34 | 1234 | | | | |
| 140 | 3 | 124 | 124 | 34 | 34 | | | | |
| 141 | | | | | | | | | |
| 142 | JORQUE 1 | 123 | 1246 | 1346 | 12 | | | | |
| 143 | 2 | 345 | 1345 | 134 | 1356 | | | | |
| 144 | 3 | 123 | 124 | 356 | 345 | | | | |
| 145 | | | | | | | | | |
| 146 | DUNN 1 | 2346 | 3456 | 34 | 346 | | | | |
| 147 | 2 | 234 | 34 | 34 | 345 | | | | |
| 148 | 3 | 346 | 36 | 34 | 3456 | | | | |
| 149 | | | | | | | | | |
| 150 | SPORA 1 | 34 | 345 | 34 | 134 | | | | |
| 151 | 2 | 46 | 14 | 46 | 346 | | | | |
| 152 | 3 | 12 | 134 | 34 | 346 | | | | |
| 153 | | | | | | | | | |
| 154 | ZAGORSKI 1 | 134 | 346 | 345 | 456 | | | | |
| 155 | 2 | 346 | 36 | 346 | 456 | | | | |
| 156 | 3 | 345 | 34 | 346 | 45 | | | | |
| 157 | | | | | | | | | |
| 158 | NGUYEN 1 | 46 | 24 | 34 | 34 | | | | |
| 159 | 2 | 34 | 24 | 234 | 3456 | | | | |
| 160 | 3 | 234 | 2345 | 34 | 34 | | | | |
| 161 | | | | | | | | | |
| 162 | GRIFFITHS 1 | 36 | 34 | 345 | 346 | | | | |
| 163 | 2 | 34 | 34 | 34 | 1234 | | | | |
| 164 | 3 | 345 | 34 | 2346 | 1236 | | | | |
| 165 | | | | | | | | | |
| 166 | LARKIN 1 | 346 | 3456 | 1234 | 1234 | | | | |
| 167 | 2 | 134 | 234 | 346 | 12346 | | | | |
| 168 | 3 | 234 | 234 | 1234 | 1246 | | | | |
| 169 | | | | | | | | | |
| 170 | MCCRAN 1 | 124 | 3456 | 56 | 56 | | | | |
| 171 | 2 | 34 | 456 | 3 | 3456 | | | | |

# STATISTICAL APPENDIX 1

RECORD OF ERRORS FOR ONE DOT AND TWO DOT ROW CHARS.

| | 1 | 2 | 3 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|
| 1 | SUBJECT | | DOT NUMBER | ERRORS (MAX | IMUM PER TR | EATMENT = 3 | ) | |
| 2 | | | | | | | | |
| 3 | | | | DOT POSITIONS | | | | |
| 4 | | 1 | 2 | 3 | 4 | 5 | 6 | |
| 5 | | | | | | | | |
| 6 | MEDINA | 1 | 3 | 1 | 1 | 0 | 1 | |
| 7 | JONES | 0 | 0 | 0 | 0 | 0 | 0 | |
| 8 | FALKINER | 2 | 2 | 1 | 1 | 1 | 2 | |
| 9 | FROST | 1 | 1 | 1 | 2 | 0 | 0 | |
| 10 | TAN | 0 | 0 | 1 | 0 | 0 | 0 | |
| 11 | GRANT | 1 | 1 | 0 | 0 | 0 | 0 | |
| 12 | PEARSON | 1 | 0 | 0 | 0 | 3 | 2 | |
| 13 | MOORE | 0 | 0 | 0 | 0 | 0 | 0 | |
| 14 | DEWAR | 1 | 1 | 0 | 1 | 1 | 0 | |
| 15 | WATMAN | 1 | 1 | 2 | 0 | 1 | 1 | |
| 16 | STRAIN | 0 | 1 | 0 | 0 | 0 | 1 | |
| 17 | FABIAN | 1 | 0 | 0 | 1 | 0 | 1 | |
| 18 | SHARP | 0 | 0 | 0 | 0 | 0 | 0 | |
| 19 | PERIC | 0 | 0 | 0 | 0 | 0 | 0 | |
| 20 | BERNOTASI | 0 | 0 | 1 | 0 | 1 | 0 | |
| 21 | TURNER | 1 | 0 | 0 | 0 | 0 | 0 | |
| 22 | MOLLISON | 0 | 1 | 0 | 2 | 0 | 2 | |
| 23 | BRIGGS | 1 | 1 | 0 | 0 | 0 | 0 | |
| 24 | HELLYAR | 0 | 0 | 1 | 0 | 3 | 2 | |
| 25 | CAMPION | 1 | 3 | 2 | 3 | 0 | 0 | |
| 26 | BAGHOMIAN | 1 | 0 | 0 | 0 | 0 | 0 | |
| 27 | HARRISON | 1 | 1 | 0 | 0 | 0 | 0 | |
| 28 | VALLING | 0 | 1 | 1 | 0 | 0 | 0 | |
| 29 | FROST | 0 | 0 | 0 | 0 | 0 | 0 | |
| 30 | COOPER | 0 | 0 | 0 | 0 | 0 | 0 | |
| 31 | MARSH | 0 | 2 | 1 | 0 | 0 | 0 | |
| 32 | NIX | 0 | 1 | 0 | 2 | 1 | 0 | |
| 33 | BOADLE | 0 | 0 | 1 | 0 | 0 | 0 | |
| 34 | BOUZEID | 1 | 1 | 1 | 0 | 0 | 0 | |
| 35 | JORQUE | 0 | 0 | 1 | 0 | 0 | 0 | |
| 36 | DUNN | 0 | 0 | 3 | 0 | 2 | 0 | |
| 37 | SPORA | 1 | 1 | 1 | 0 | 0 | 0 | |
| 38 | ZAGORSKI | 1 | 2 | 1 | 0 | 0 | 1 | |
| 39 | NGUYEN | 1 | 0 | 2 | 0 | 0 | 0 | |
| 40 | GRIFFITHS | 2 | 0 | 0 | 0 | 2 | 0 | |
| 41 | LARKIN | 1 | 1 | 0 | 0 | 1 | 0 | |
| 42 | MCCRAN | 1 | 0 | 0 | 0 | 0 | 0 | |
| 43 | | | | | | | | |
| 44 | | | | | | | | |
| 45 | TOTAL ERRORS | 22 | 25 | 22 | 13 | 16 | 13 | |
| 46 | TOTAL CORRECT | 88 | 85 | 88 | 97 | 94 | 97 | |
| 47 | | | | | | | | |
| 48 | % ERRORS | 20 | 23 | 20 | 12 | 15 | 12 | |
| 49 | % CORRECT | 80 | 77 | 80 | 88 | 85 | 88 | |
| 50 | | | | | | | | |
| 51 | | | | | | | | |
| 52 | | | | | | | | |
| 53 | | | | | | | | |
| 54 | | | | | | | | |
| 55 | | | | | | | | |
| 56 | | | | | | | | |
| 57 | | | | | | | | |

# STATISTICAL APPENDIX 1

RECORD OF ERRORS FOR ONE DOT AND TWO DOT ROW CHARS.

| | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
|---|---|---|---|---|---|---|---|
| 1 | SUBJECT | DOT NUMBER | ERRORS (MAX | IMUM PER TR | EATMENT = 3 ) | | |
| 2 | | | | | | | |
| 3 | | ROW | POSITIONS | | | | |
| 4 | | TOP ROW | MID ROW | BOTTOM ROW | | | |
| 5 | | | | | | | |
| 6 | MEDINA | 2 | 0 | 0 | | | |
| 7 | JONES | 0 | 0 | 1 | | | |
| 8 | FALKINER | 0 | 1 | 1 | | | |
| 9 | FROST | 1 | 1 | 1 | | | |
| 10 | TAN | 0 | 0 | 0 | | | |
| 11 | GRANT | 0 | 2 | 1 | | | |
| 12 | PEARSON | 0 | 1 | 0 | | | |
| 13 | MOORE | 2 | 1 | 0 | | | |
| 14 | DEWAR | 0 | 1 | 1 | | | |
| 15 | WATMAN | 0 | 0 | 3 | | | |
| 16 | STRAIN | 0 | 2 | 0 | | | |
| 17 | FABIAN | 1 | 2 | 0 | | | |
| 18 | SHARP | 1 | 1 | 0 | | | |
| 19 | PERIC | 0 | 1 | 0 | | | |
| 20 | BERNOTASI | 1 | 1 | 3 | | | |
| 21 | TURNER | 0 | 0 | 2 | | | |
| 22 | MOLLISON | 3 | 0 | 0 | | | |
| 23 | BRIGGS | 3 | 1 | 1 | | | |
| 24 | HELLYAR | 1 | 1 | 1 | | | |
| 25 | CAMPION | 1 | 0 | 0 | | | |
| 26 | BAGHOMIAN | 0 | 0 | 0 | | | |
| 27 | HARRISON | 0 | 1 | 3 | | | |
| 28 | VALLING | 3 | 3 | 2 | | | |
| 29 | FROST | 0 | 1 | 0 | | | |
| 30 | COOPER | 0 | 0 | 0 | | | |
| 31 | MARSH | 3 | 2 | 2 | | | |
| 32 | NIX | 1 | 0 | 2 | | | |
| 33 | BOADLE | 1 | 1 | 2 | | | |
| 34 | BOUZEID | 1 | 1 | 1 | | | |
| 35 | JORQUE | 1 | 0 | 1 | | | |
| 36 | DUNN | 1 | 0 | 1 | | | |
| 37 | SPORA | 0 | 0 | 0 | | | |
| 38 | ZAGORSKI | 1 | 1 | 1 | | | |
| 39 | NGUYEN | 0 | 0 | 0 | | | |
| 40 | GRIFFITHS | 0 | 1 | 2 | | | |
| 41 | LARKIN | 1 | 1 | 2 | | | |
| 42 | MCCRAN | 2 | 0 | 2 | | | |
| 43 | | | | | | | |
| 44 | | | | | | | |
| 45 | TOTAL ERRORS | 31 | 28 | 36 | | | |
| 46 | TOTAL CORRECT | 79 | 82 | 74 | | | |
| 47 | | | | | | | |
| 48 | % ERRORS | 28 | 25 | 33 | | | |
| 49 | % CORRECT | 72 | 75 | 67 | | | |
| 50 | | | | | | | |
| 51 | | | | | | | |
| 52 | | | | | | | |
| 53 | | | | | | | |
| 54 | | | | | | | |
| 55 | | | | | | | |
| 56 | | | | | | | |
| 57 | | | | | | | |

## Statistical Appendix 1

Data to test of the regional sensitivity hypotheses could not be subjected directly to a test of significance in view of the non-independent nature of the measurements. To overcome this disability the data was recalculated to permit assignment of subjects based on frequency of errors in reporting dot number for each of the three rows of the braille matrix. Subjects were accordingly assigned to one of three groups corresponding to the three horizontal regions of the matrix. Instances of equal errors over all three regions were discarded and equal frequencies in two of the three regions were allocated a half score for each of the two regions. Scoring was done for responses to all one dot stimuli and two dot row stimuli , the two sets of stimuli used in test of the sensitivity hypotheses.

Based on this method of scoring Chi-square tests were applied as follows :

**One dot Stimuli**

| | Highest Error Frequency in: Top Row | Mid Row | Bottom Row |
|---|---|---|---|
| Observed Frequency | 15.5 | 9.5 | 4 |
| Expected Frequency | 9.67 | 9.67 | 9.67 |

$$\text{Chi Square} = \sum \frac{(E - O)^2}{E} = 6.84$$

With 2 d.f. $p < .05$

**Two Dot Row Stimuli**

| | Highest Error Frequency in: Top Row | Mid Row | Bottom Row |
|---|---|---|---|
| Observed Frequency | 8.5 | 8.0 | 11.5 |
| Expected Frequency | 9.33 | 9.33 | 9.33 |

$$\text{Chi Square} = \sum \frac{(E-O)^2}{E} = 0.76$$

With 2 d.f. $.7 > p > .5$

STATISTICAL APPENDIX 2

| | NAME | SEX | SERIES | 1 DOT | 2 DOT |
|---|---|---|---|---|---|
| | | X1 | | Y1 | Y2 |
| 1 | MEDINA | MALE | SERIES 2 | 17 | 19 |
| 2 | JONES | FEM... | SERIES 2 | 17 | 18 |
| 3 | FALKIN... | FEM... | SERIES 2 | 9 | 6 |
| 4 | FROST | MALE | SERIES 2 | 10 | 8 |
| 5 | TAN | FEM... | SERIES 2 | 20 | 16 |
| 6 | GRANT | FEM... | SERIES 2 | 11 | 17 |
| 7 | PEARS... | MALE | SERIES 2 | 17 | 11 |
| 8 | MOORE | MALE | SERIES 2 | 20 | 18 |
| 9 | DEWAR | FEM... | SERIES 2 | 19 | 15 |
| 10 | WATMAN | FEM... | SERIES 2 | 12 | 15 |
| 11 | STRAIN | MALE | SERIES 2 | 12 | 16 |
| 12 | FABIAN | MALE | SERIES 2 | 17 | 16 |
| 13 | SHARP | FEM... | SERIES 2 | 17 | 16 |
| 14 | PERIC | FEM... | SERIES 2 | 23 | 19 |
| 15 | BERNO... | FEM... | SERIES 2 | 13 | 12 |
| 16 | TURNER | MALE | SERIES 2 | 15 | 9 |
| 17 | MOLLIS... | FEM... | SERIES 1 | 19 | 15 |
| 18 | BRIGGS | FEM... | SERIES 1 | 13 | 15 |
| 19 | HELLYAR | FEM... | SERIES 1 | 12 | 13 |
| 20 | CAMPI... | FEM... | SERIES 1 | 6 | 8 |
| 21 | BAGHO... | FEM... | SERIES 1 | 18 | 14 |
| 22 | HARRI... | MALE | SERIES 1 | 15 | 11 |
| 23 | VALLING | FEM... | SERIES 1 | 11 | 17 |
| 24 | FROST | FEM... | SERIES 1 | 12 | 12 |
| 25 | COOPER | FEM... | SERIES 1 | 21 | 20 |
| 26 | MARSH | MALE | SERIES 1 | 17 | 15 |
| 27 | NIX | FEM... | SERIES 1 | 20 | 15 |
| 28 | BOADLE | FEM... | SERIES 1 | 19 | 9 |
| 29 | BOUZEID | FEM... | SERIES 1 | 14 | 15 |
| 30 | JORQUE | MALE | SERIES 1 | 14 | 10 |
| 31 | DUNN | FEM... | SERIES 1 | 14 | 11 |
| 32 | SPORA | FEM... | SERIES 1 | 20 | 11 |
| 33 | ZAGOR... | MALE | SERIES 1 | 18 | 20 |
| 34 | NGUYEN | MALE | SERIES 1 | 9 | 10 |
| 35 | GRIFFI... | FEM... | SERIES 1 | 9 | 16 |
| 36 | LARKIN | MALE | SERIES 1 | 9 | 17 |

3 DOT CODES: CORRECT DOT NUMBER RESPONSES FOR CODES WITH: (1) ONE DOT IN FRONT EDGE (2) TWO DOTS IN FRONT EDGE.
(MAXIMUM SCORE IN EACH SET 30 CORRECT RESPONSES)

# 3 DOT CODES: ANALYSIS BY NO. OF DOTS IN FRONT EDGE

**One Factor ANOVA $X_1$: SERIES $Y_1$: 1 DOT**

Analysis of Variance Table

| Source: | DF: | Sum Squares: | Mean Square: | F-test: |
|---|---|---|---|---|
| Between groups | 1 | 10.035 | 10.035 | .56 |
| Within groups | 34 | 608.938 | 17.91 | p = .4593 |
| Total | 35 | 618.972 | | |

Model II estimate of between component variance = -7.875

1

**One Factor ANOVA $X_1$: SERIES $Y_1$: 1 DOT**

| Group: | Count: | Mean: | Std. Dev.: | Std. Error: |
|---|---|---|---|---|
| SERIES 1 | 20 | 14.5 | 4.383 | .98 |
| SERIES 2 | 16 | 15.562 | 4.033 | 1.008 |

2

**One Factor ANOVA $X_1$: SERIES $Y_1$: 1 DOT**

| Comparison: | Mean Diff.: | Fisher PLSD: | Scheffe F-test: | Dunnett t: |
|---|---|---|---|---|
| SERIES 1 vs. SERIES 2 | -1.062 | 2.885 | .56 | .749 |

3

STATISTICAL APPENDIX 2

3 DOT CODES: ANALYSIS BY NO. OF DOTS IN FRONT EDGE

**One Factor ANOVA $X_1$: SERIES $Y_2$: 2 DOT**

Analysis of Variance Table

| Source: | DF: | Sum Squares: | Mean Square: | F-test: |
|---|---|---|---|---|
| Between groups | 1 | 4.835 | 4.835 | .353 |
| Within groups | 34 | 466.138 | 13.71 | p = .5566 |
| Total | 35 | 470.972 | | |

Model II estimate of between component variance = -8.875

4

**One Factor ANOVA $X_1$: SERIES $Y_2$: 2 DOT**

| Group: | Count: | Mean: | Std. Dev.: | Std. Error: |
|---|---|---|---|---|
| SERIES 1 | 20 | 13.7 | 3.42 | .765 |
| SERIES 2 | 16 | 14.438 | 4.033 | 1.008 |

5

**One Factor ANOVA $X_1$: SERIES $Y_2$: 2 DOT**

| Comparison: | Mean Diff.: | Fisher PLSD: | Scheffe F-test: | Dunnett t: |
|---|---|---|---|---|
| SERIES 1 vs. SERIES 2 | -.738 | 2.524 | .353 | .594 |

6

# STATISTICAL APPENDIX 1

## 3 DOT CODES: ANALYSIS BY NO. OF DOTS IN FRONT EDGE

**One Factor ANOVA $X_1$: SEX $Y_1$: 1 DOT**

Analysis of Variance Table

| Source: | DF: | Sum Squares: | Mean Square: | F-test: |
|---|---|---|---|---|
| Between groups | 1 | 2.591 | 2.591 | .143 |
| Within groups | 34 | 616.381 | 18.129 | p = .7077 |
| Total | 35 | 618.972 | | |

Model II estimate of between component variance = −15.538

1

**One Factor ANOVA $X_1$: SEX $Y_1$: 1 DOT**

| Group: | Count: | Mean: | Std. Dev.: | Std. Error: |
|---|---|---|---|---|
| MALE | 13 | 14.615 | 3.595 | .997 |
| FEMALE | 23 | 15.174 | 4.579 | .955 |

2

**One Factor ANOVA $X_1$: SEX $Y_1$: 1 DOT**

| Comparison: | Mean Diff.: | Fisher PLSD: | Scheffe F-test: | Dunnett t: |
|---|---|---|---|---|
| MALE vs. FEMALE | -.559 | 3.003 | .143 | .378 |

3

# 3 DOT CODES: ANALYSIS BY NO. OF DOTS IN FRONT EDGE

**One Factor ANOVA $X_1$: SEX $Y_2$: 2 DOT**

Analysis of Variance Table

| Source: | DF: | Sum Squares: | Mean Square: | F-test: |
|---|---|---|---|---|
| Between groups | 1 | .671 | .671 | .049 |
| Within groups | 34 | 470.301 | 13.832 | p = .827 |
| Total | 35 | 470.972 | | |

Model II estimate of between component variance = -13.161

4

**One Factor ANOVA $X_1$: SEX $Y_2$: 2 DOT**

| Group: | Count: | Mean: | Std. Dev.: | Std. Error: |
|---|---|---|---|---|
| MALE | 13 | 13.846 | 4.14 | 1.148 |
| FEMALE | 23 | 14.13 | 3.468 | .723 |

5

**One Factor ANOVA $X_1$: SEX $Y_2$: 2 DOT**

| Comparison: | Mean Diff.: | Fisher PLSD: | Scheffe F-test: | Dunnett t: |
|---|---|---|---|---|
| MALE vs. FEMALE | -.284 | 2.623 | .049 | .22 |

6